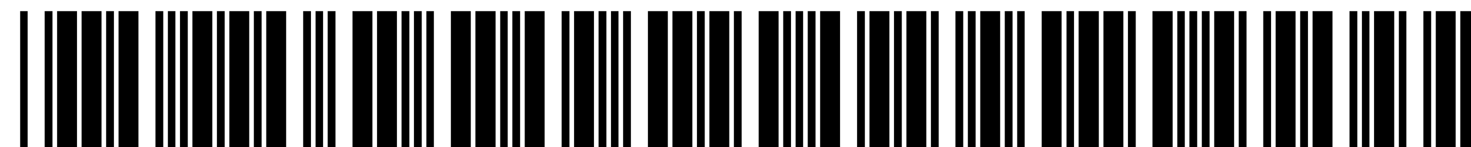

(12) **United States Patent**
Kadoguchi et al.

(10) **Patent No.: US 9,059,145 B2**
(45) **Date of Patent: Jun. 16, 2015**

(54) **POWER MODULE, METHOD FOR MANUFACTURING POWER MODULE, AND MOLDING DIE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 111 days.

(21) Appl. No.: **13/590,707**

(22) Filed: **Aug. 21, 2012**

(65) **Prior Publication Data**

US 2013/0050947 A1 Feb. 28, 2013

(30) **Foreign Application Priority Data**

Aug. 25, 2011 (JP) 2011-184080
Jun. 8, 2012 (JP) 2012-130772

(51) **Int. Cl.**
H05K 7/20 (2006.01)
H01L 23/433 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01L 23/4334*** (2013.01); *Y10T 29/49002* (2015.01); ***H01L 23/051*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H05K 7/2098–7/20945; H05K 7/20218; H05K 7/20254; H05K 5/00; H05K 5/0026; H05K 5/0082; H05K 5/0021; H05K 5/069; H05K 7/20; H05K 7/00; H05K 7/1422; H05K 1/0218–1/0219; H05K 1/00; H05K 3/00; H05K 9/00; H01L 23/473; G06F 1/16–1/1654; G06F 1/1656; G06F 1/1662–1/1681; G06F 1/20; G06F 1/203; G06F 1/206; G06F 2200/201; G06F 2200/202; G06F 2200/203; H01G 2/00; H01G 4/00; H01G 5/00; H01G 7/00; H01G 9/00–9/155; H01G 11/00; H02G 3/00; H02G 5/00; H02G 7/00; H02G 9/00; H02G 11/00; H02G 13/00; H02G 15/00; H01B 7/00; H01B 11/00; H01B 17/00; H01R 4/00; H01R 9/00; H01R 13/00; H01K 1/00; H01K 3/00; H02B 1/00; H01H 37/00
USPC 361/679.46–679.54, 688–723; 165/80.1–80.5, 104.33, 185; 174/15.1–15.2, 16.1–16.3; 363/141; 257/712–722, E23.088
See application file for complete search history.

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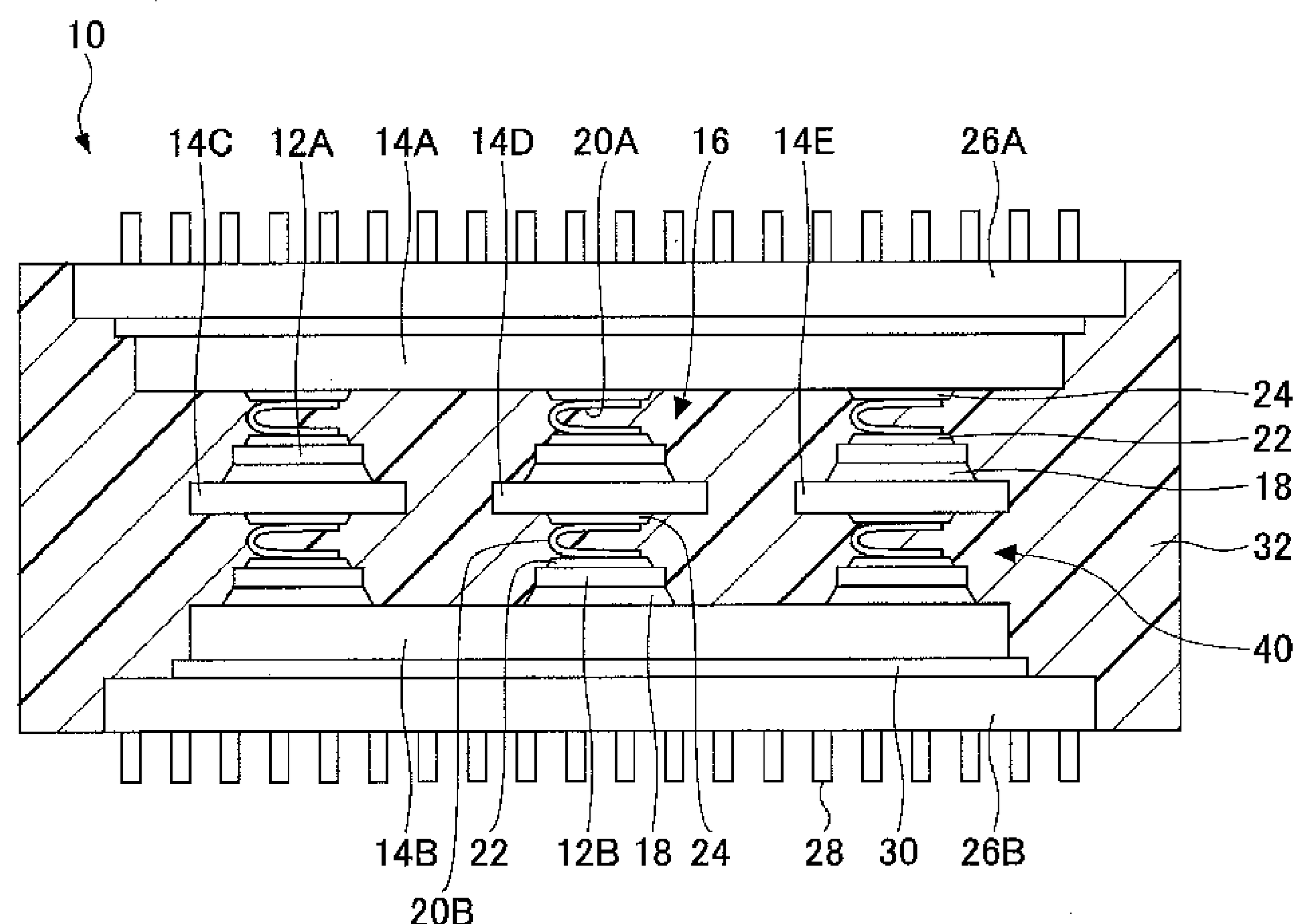
(57) **ABSTRACT**

A power module is disclosed that includes a semiconductor element, a first cooling member and a second cooling member configured to sandwich the semiconductor element therebetween, a frame member configured to support the semiconductor element between the first cooling member and the second cooling member and molded resin disposed between the first cooling member and the second cooling member, wherein the frame member includes an adjusting member which adjusts a distance between the first cooling member and the second cooling member.

2 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

H01L 23/051	(2006.01)
H01L 25/07	(2006.01)
H01L 23/473	(2006.01)
H01L 23/31	(2006.01)
H01L 21/56	(2006.01)

(52) **U.S. Cl.**

CPC *H01L23/3107* (2013.01); *H01L 21/565* (2013.01); *H01L 2924/0002* (2013.01); ***H01L 25/071*** (2013.01)

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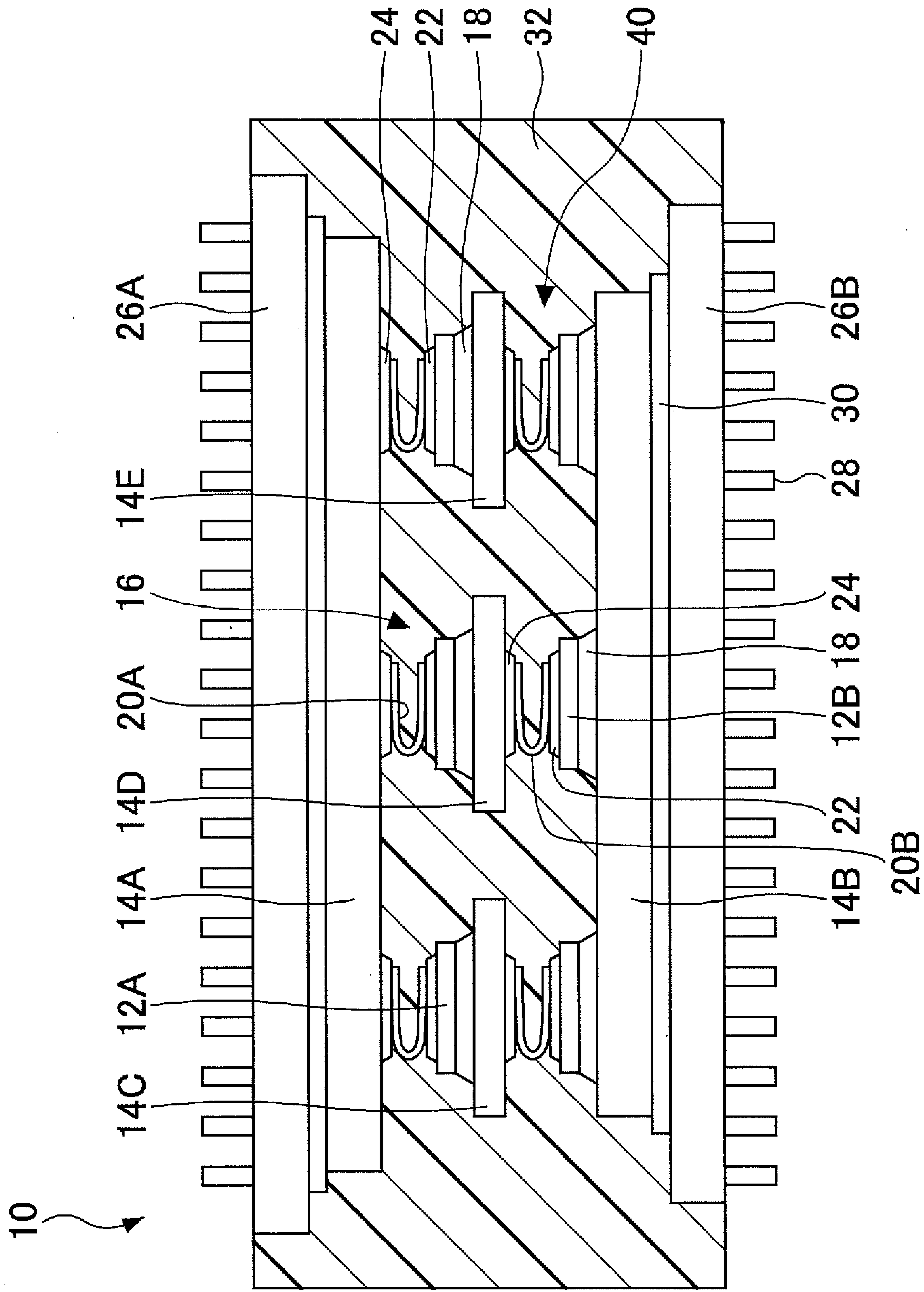

FIG.1

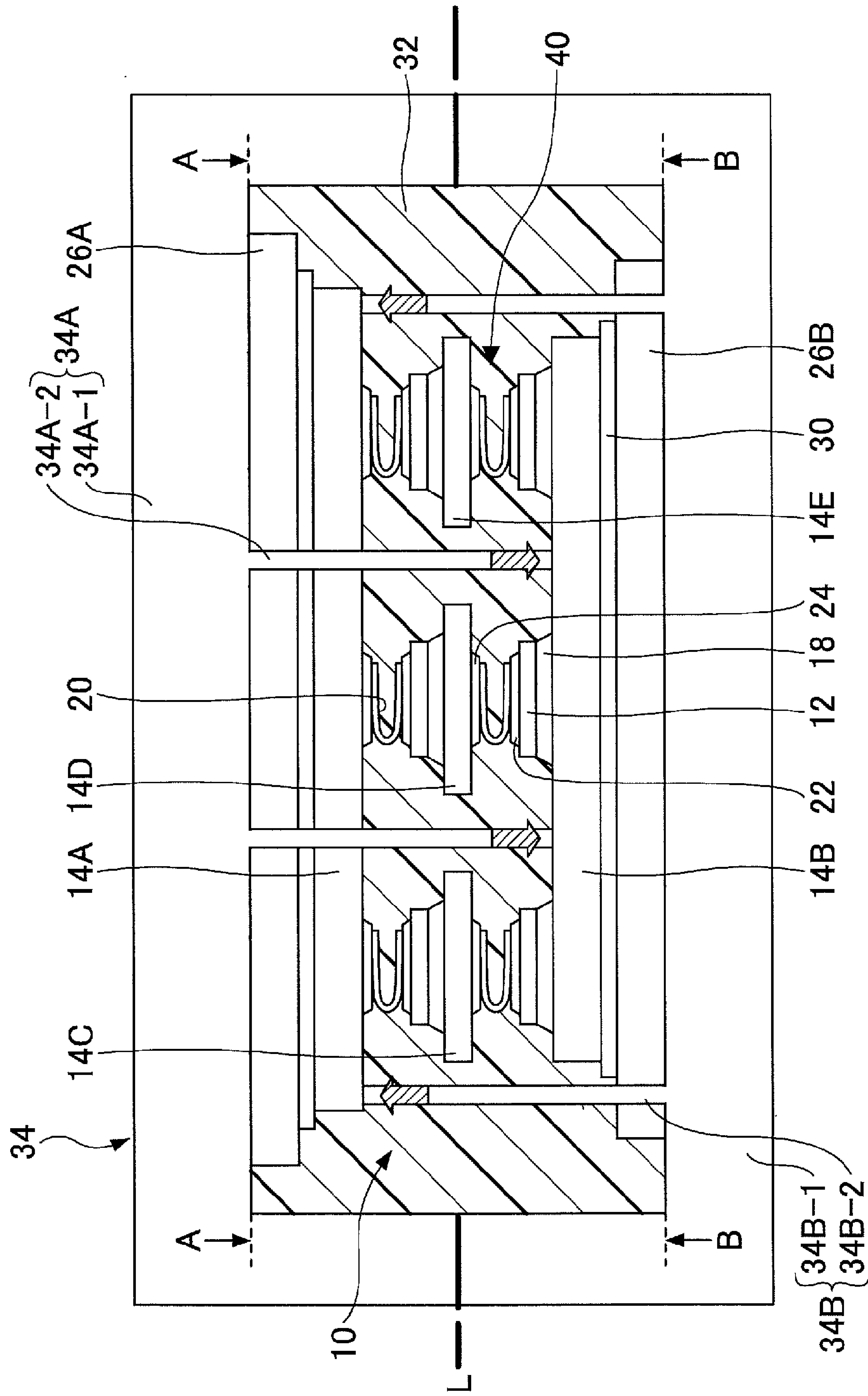

FIG.2

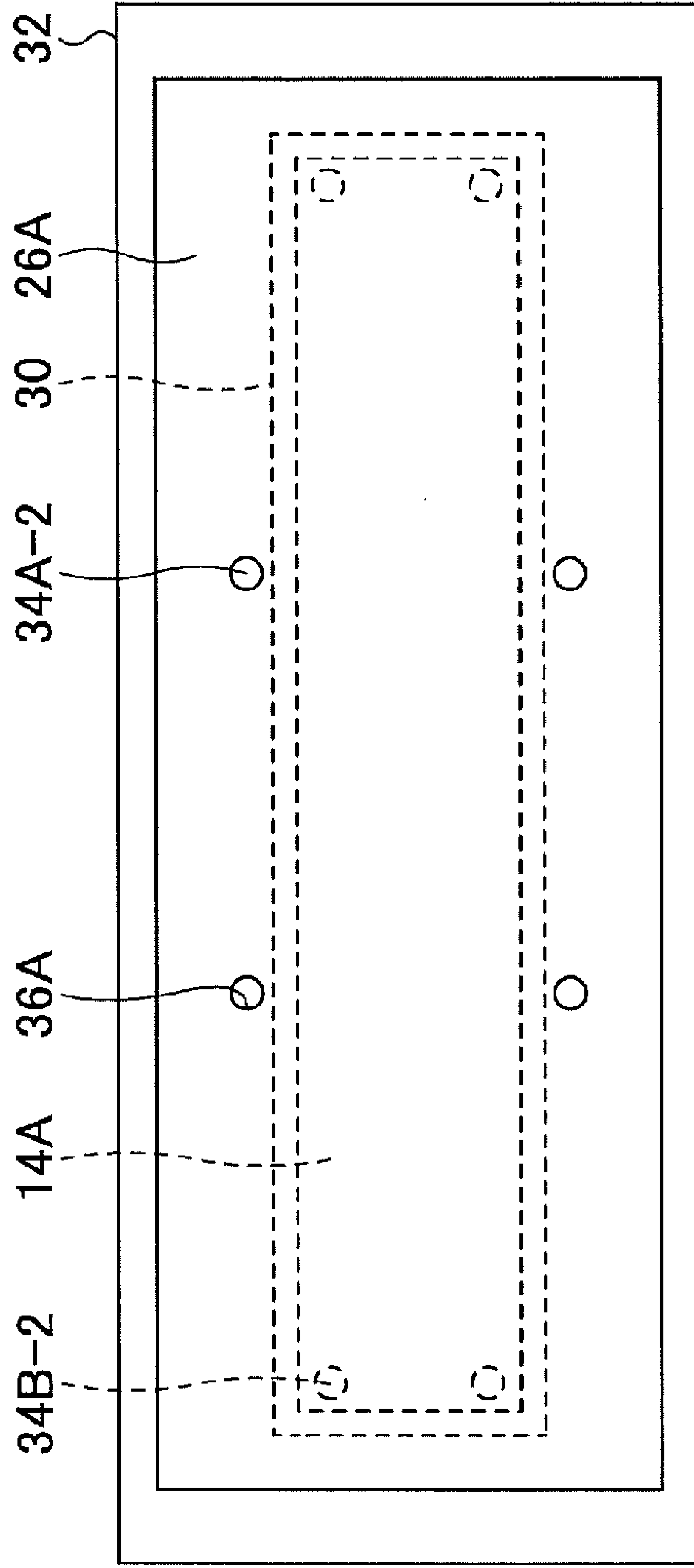

FIG.3A

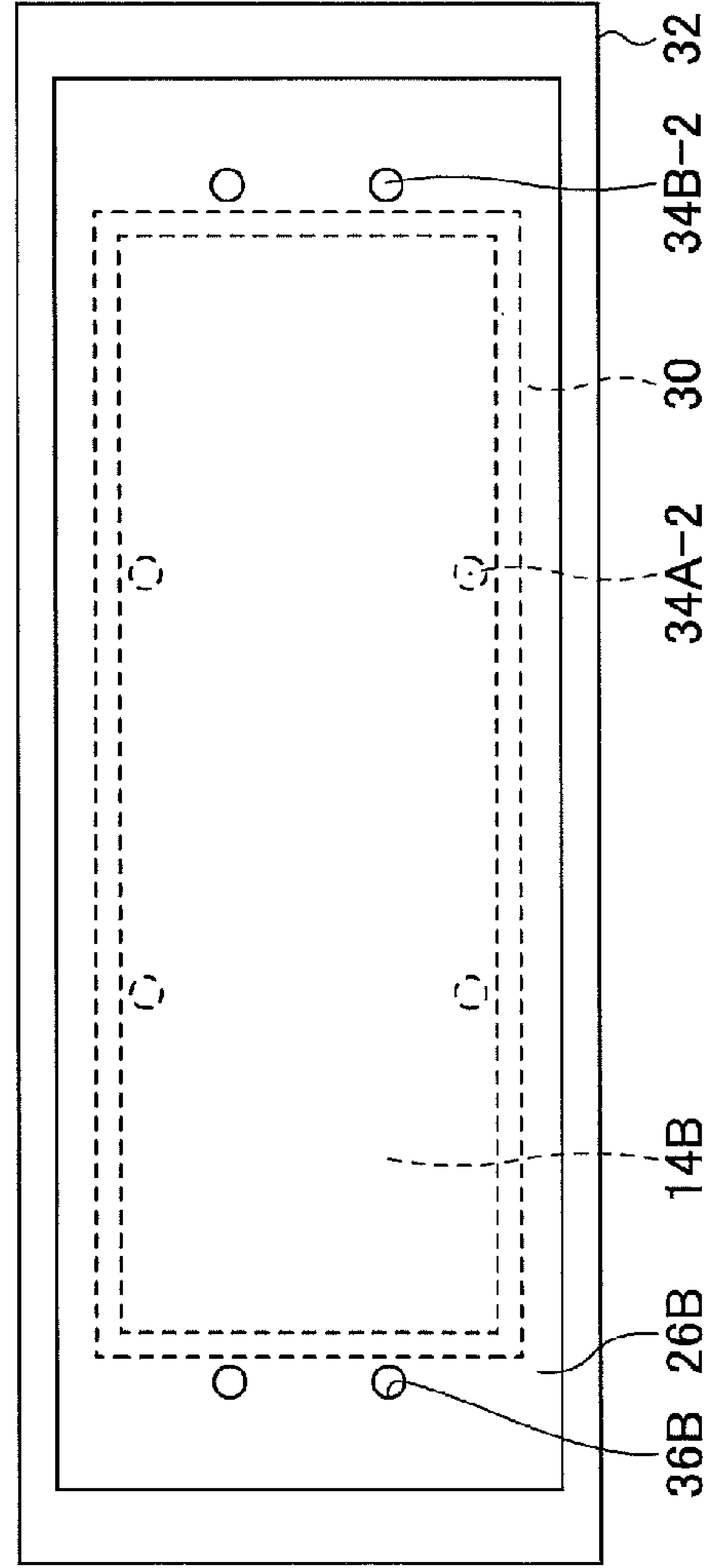

FIG.3B

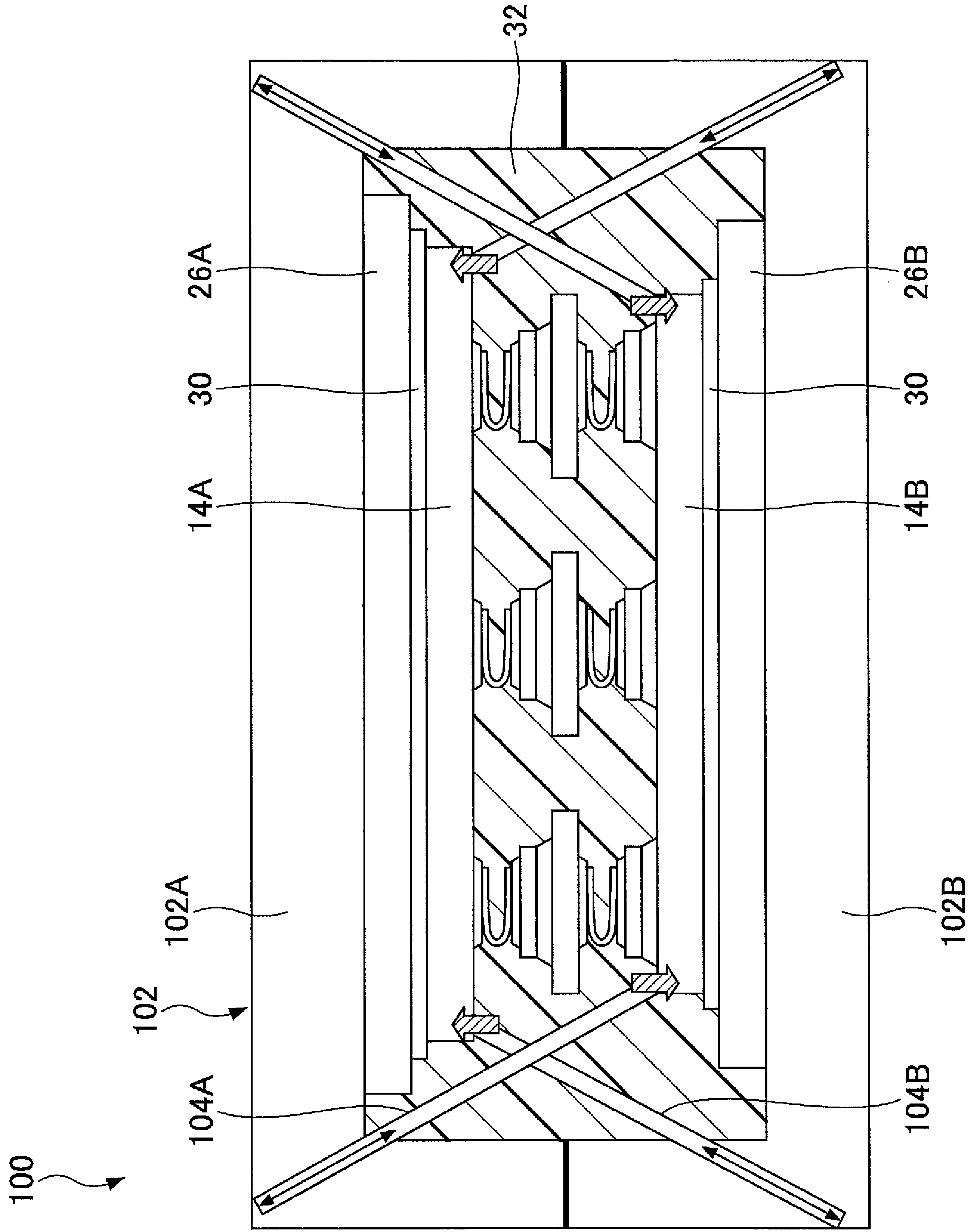

FIG.4

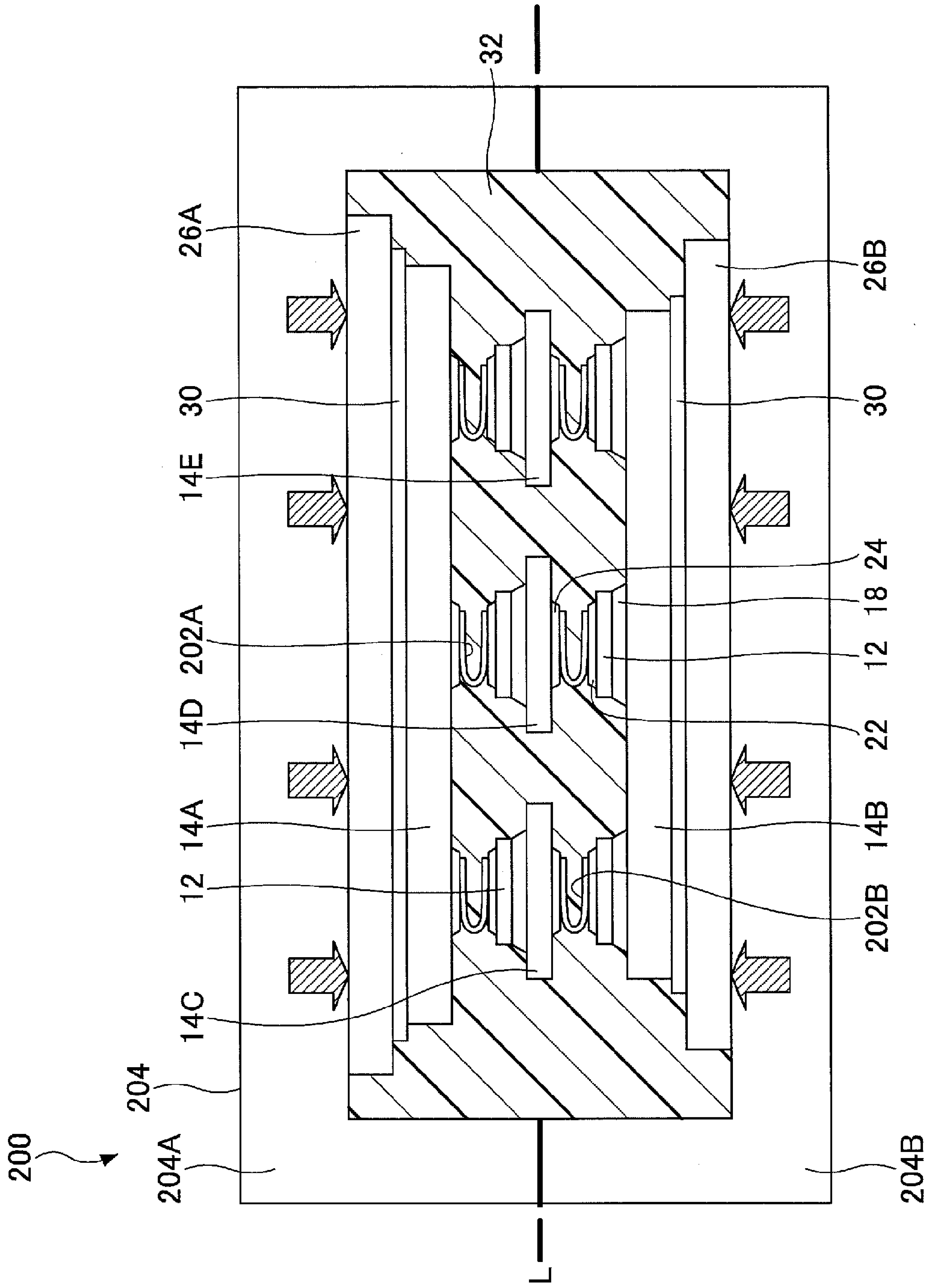

FIG.5

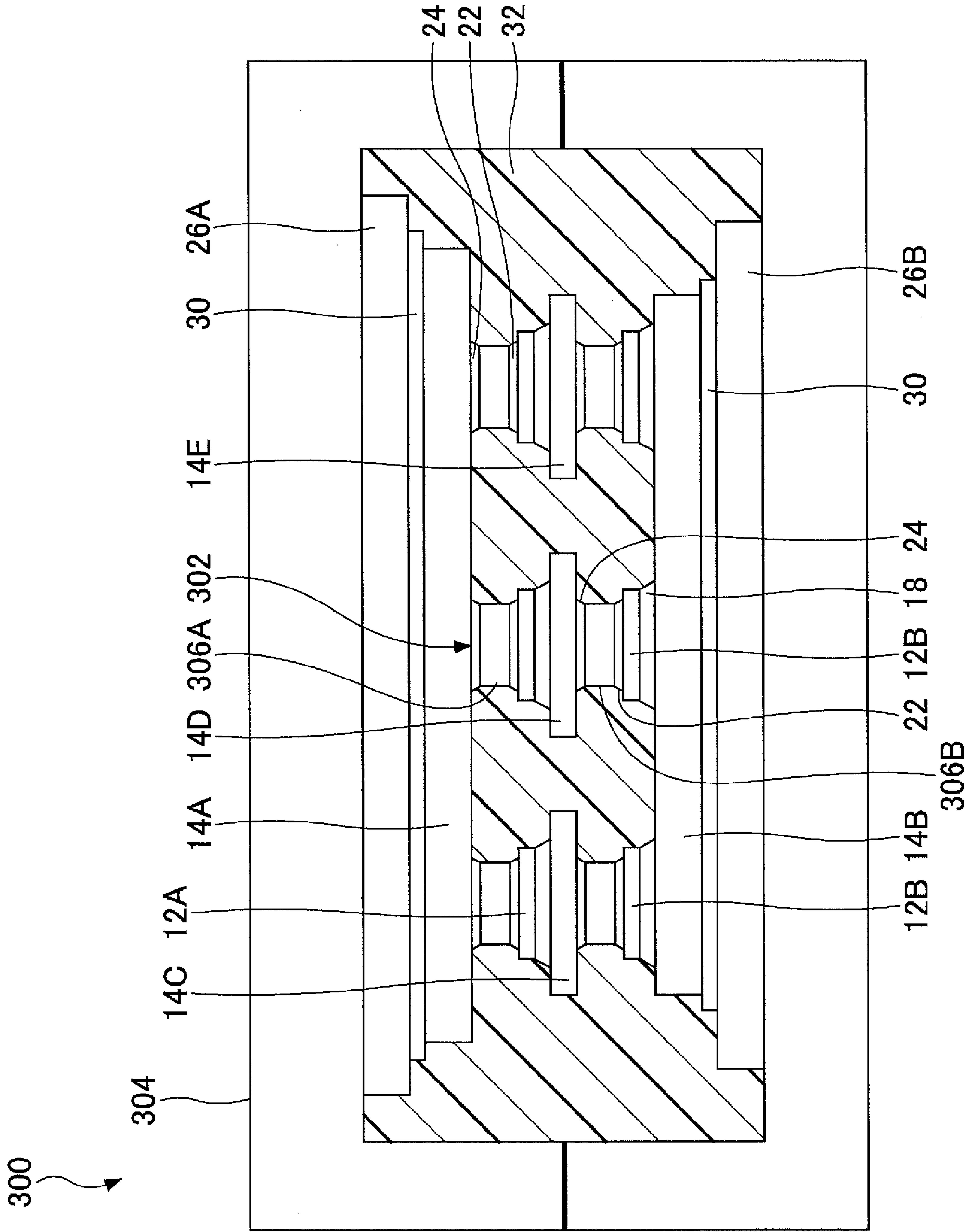

FIG.6

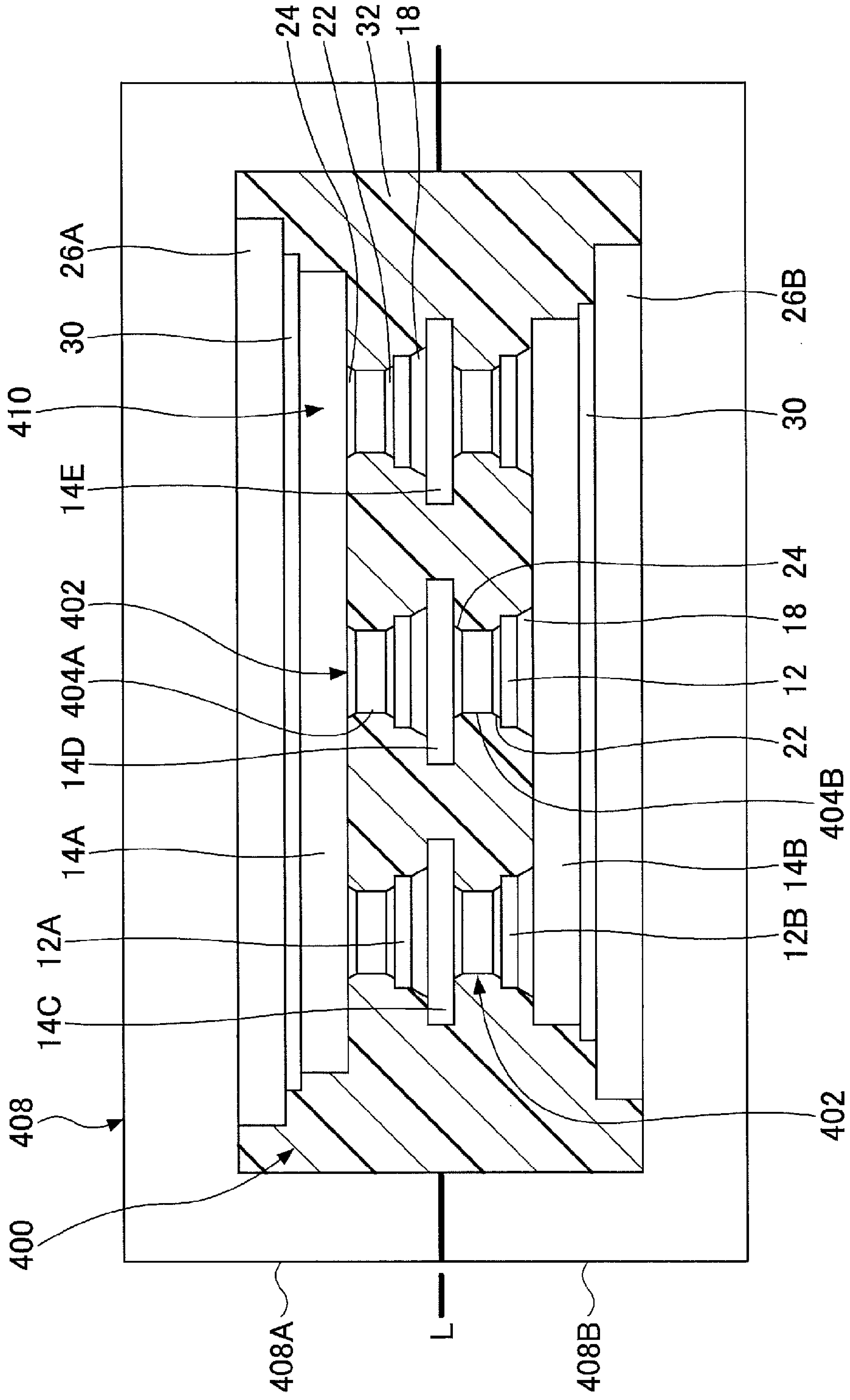

FIG.7

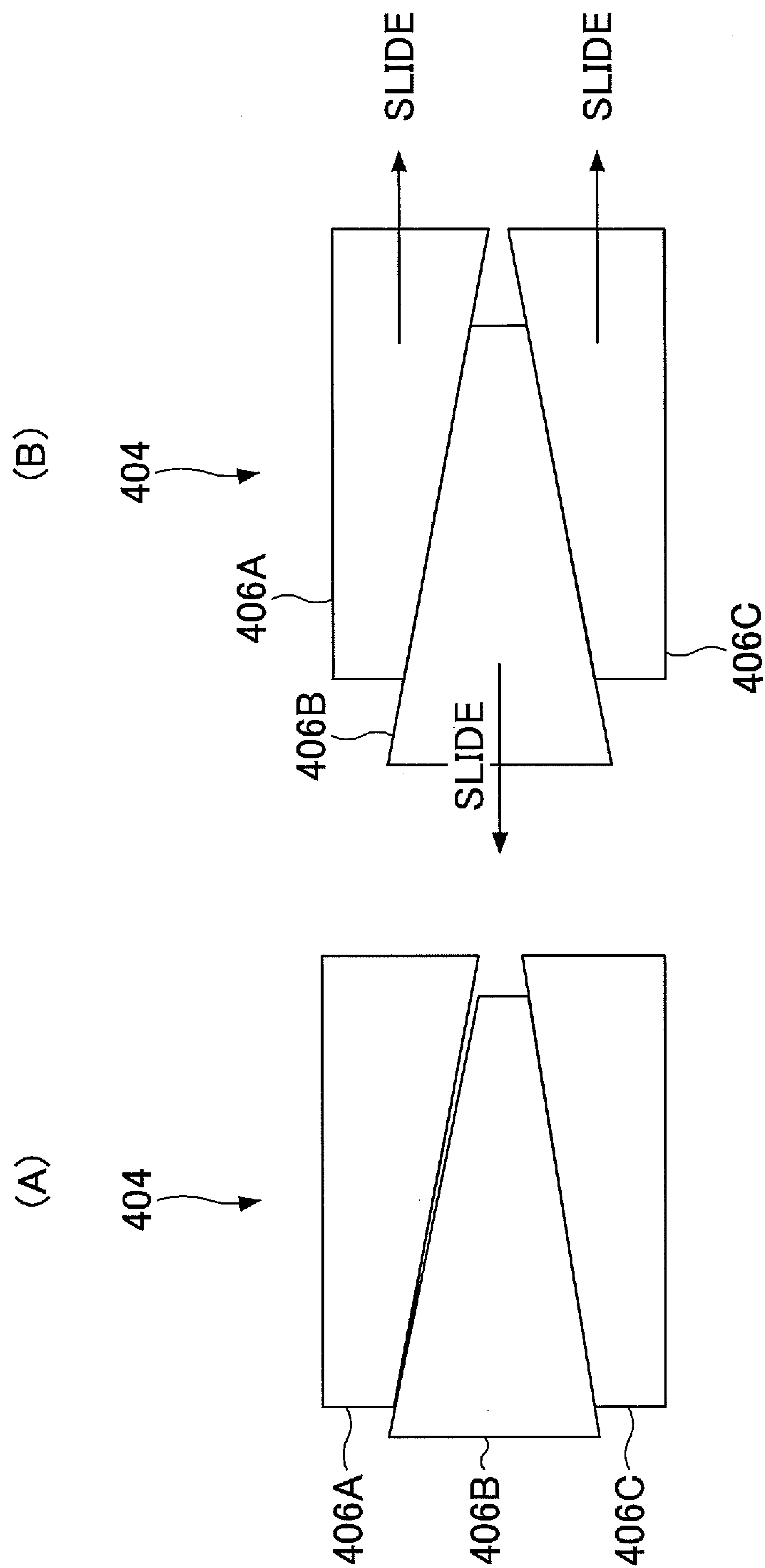

FIG.8

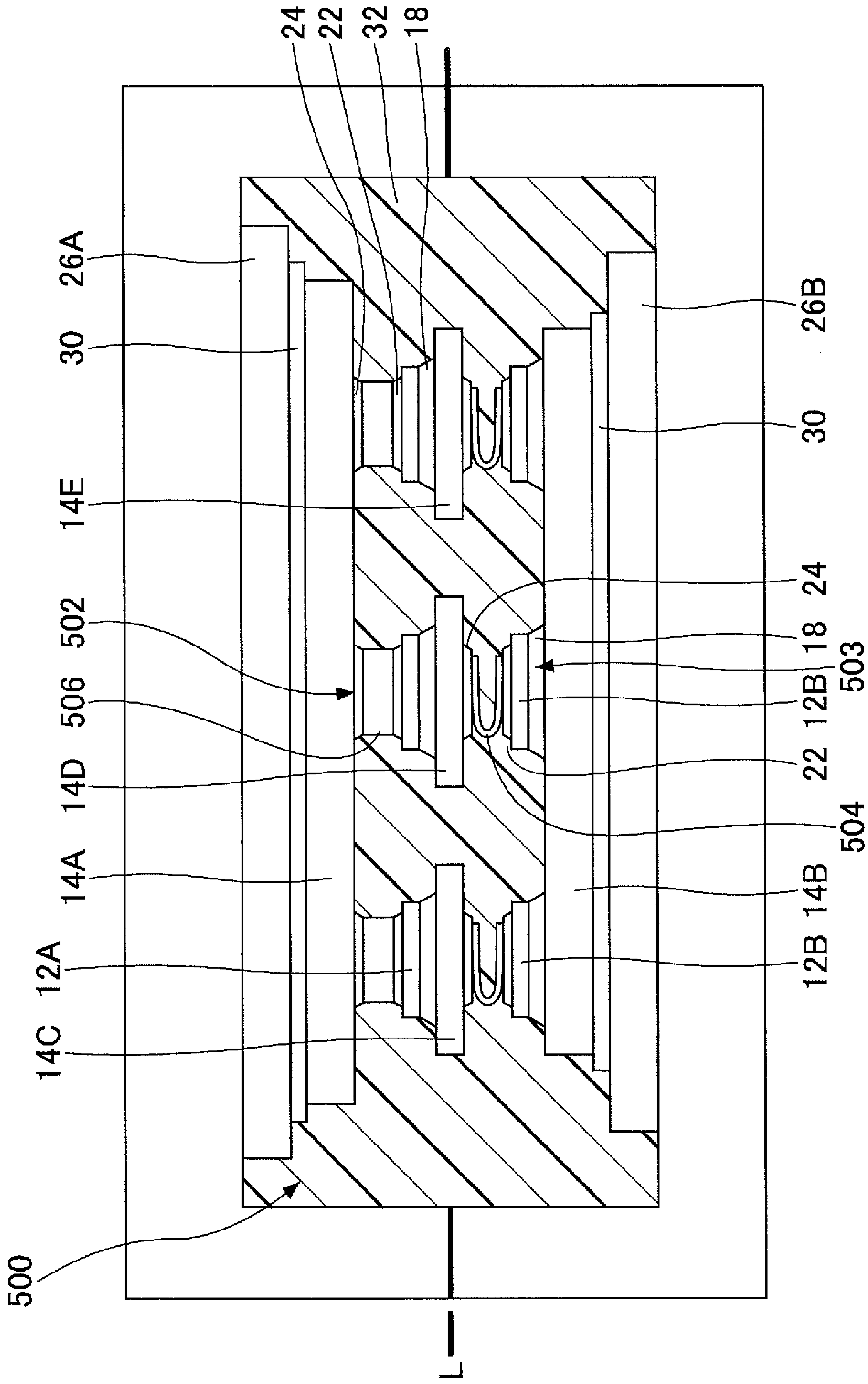

FIG.9

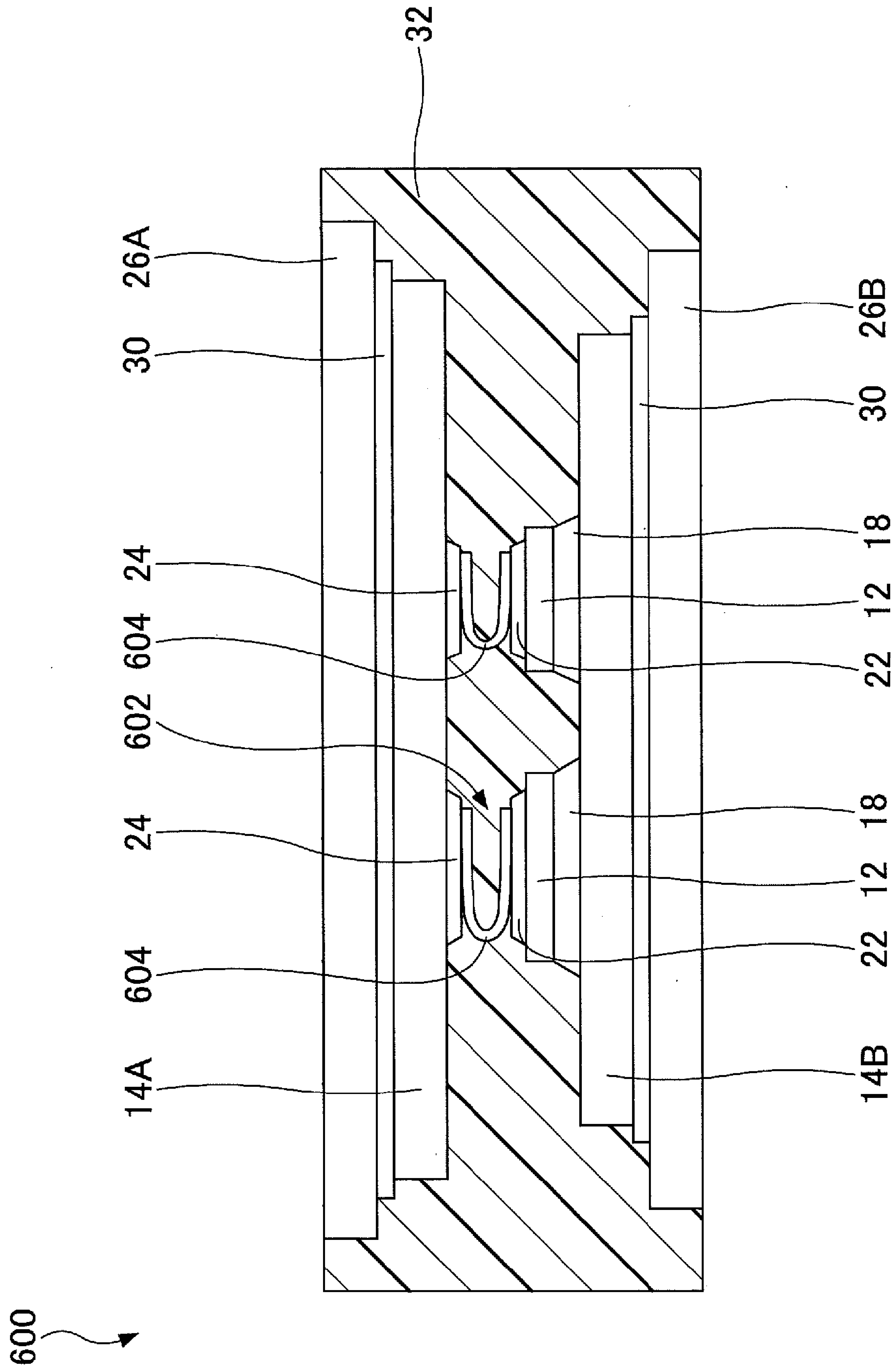

FIG.10

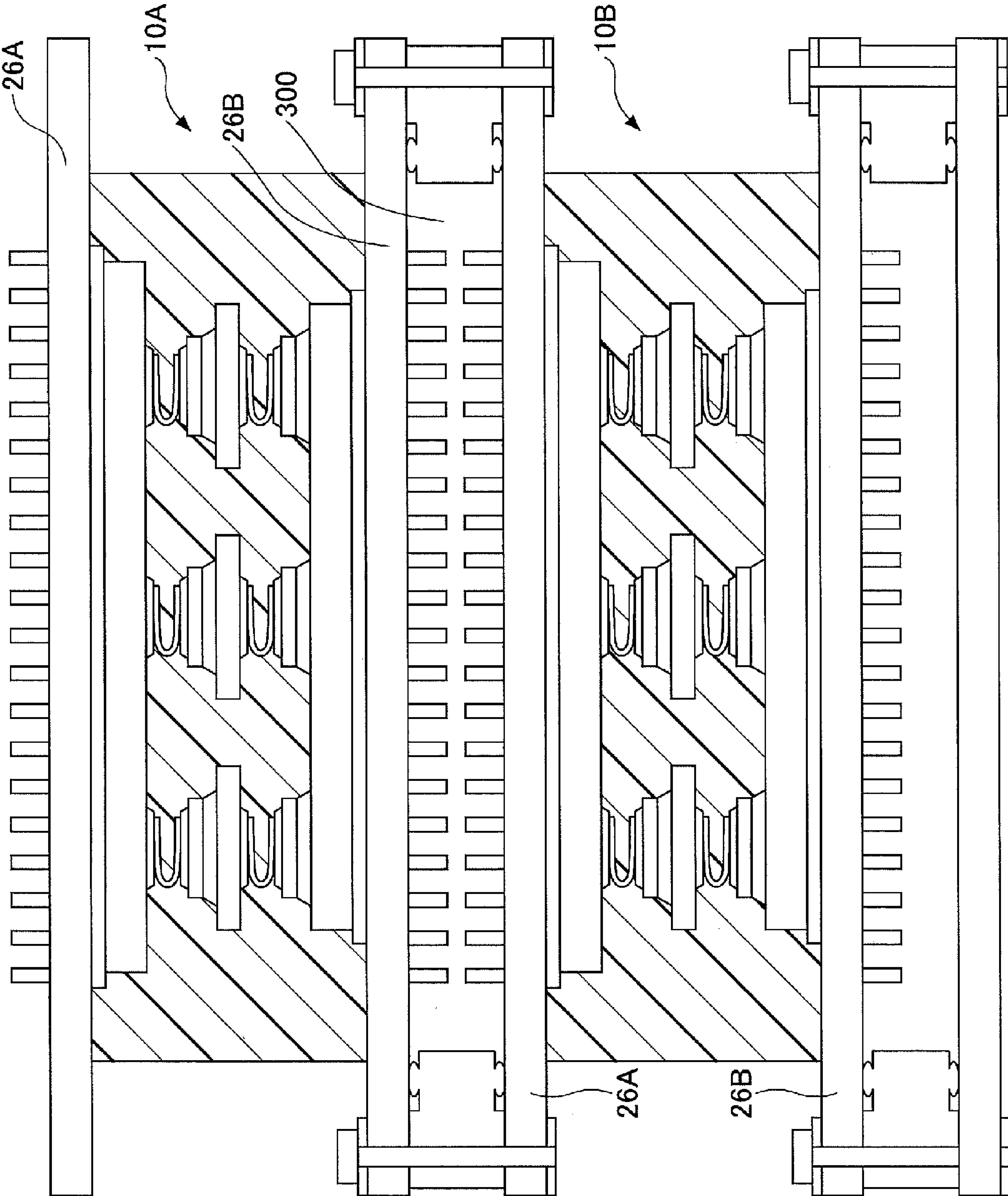

FIG.11

POWER MODULE, METHOD FOR MANUFACTURING POWER MODULE, AND MOLDING DIE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a power module which includes a semiconductor element, cooling members disposed on both surfaces of the semiconductor element, respectively, and a molded resin which seals the semiconductor element between the cooling members. The present invention also relates to a method for manufacturing the power module and a molding die used for molding the power module.

2. Description of the Related Art

Conventionally, there has been a power module including a semiconductor element molded by a resin (see, e.g., Patent Document 1). When the semiconductor element is being driven, the semiconductor element generates heat. The power module is cooled by the cooling members that are disposed on both surfaces of the semiconductor element, respectively. The power module is manufactured by supplying the resin between the two cooling members that sandwich the semiconductor element.

[Patent Document 1] Japanese Patent Application Publication No. 2006-049542

The molding process of the power module disclosed in patent document 1 is realized by supplying the resin into a molding area located between the cooling members that are held by a designated molding die. The molding area is an area in which the semiconductor element, a metal block, a solder or the like are stacked and molded by the resin. In the molding process, a dimensional tolerance which meets the dimension of the molding die is required for the molding area.

Since it is not easy for the molded resin to meet the dimensional tolerance, the resin may leak from the molding die. On the other hand, the semiconductor element, the solder or the like which is disposed in the molding area may not be held by the molding die appropriately and may be broken by a molding pressure.

SUMMARY OF THE INVENTION

It is an object of embodiments of the present invention to provide a power module, a method for manufacturing the power module and a molding die used for molding the power module that can realize dimensional management of the power module including a semiconductor element and cooling members disposed on respective sides of the semiconductor element.

Features and advantages of the present invention will be set forth in the description which follows, and in part will become apparent from the description and the accompanying drawings, or may be learned by practice of the invention according to the teachings provided in the description. Objects as well as other features and advantages of the present invention will be realized and attained by a semiconductor element particularly pointed out in the specification in such full, clear, concise, and exact terms as to enable a person having ordinary skill in the art to practice the invention.

To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, an embodiment of the present invention provides a power module including a semiconductor element; a first cooling member and a second cooling member configured to sandwich the semiconductor element therebetween; a frame member configured to support the semiconductor element between the first cooling member and the second cooling member; and a molded resin disposed between the first cooling member and the second cooling member, wherein the frame member includes an adjusting member which adjusts a distance between the first cooling member and the second cooling member.

Another embodiment of the present invention provides a method of manufacturing a power module including a semiconductor element, a first cooling member and a second cooling member configured to sandwich the semiconductor element therebetween, a frame member configured to support the semiconductor element between the first cooling member and the second cooling member and configured to include an adjusting member which adjusts a distance between the first cooling member and the second cooling member, and a molded resin disposed between the first cooling member and the second cooling member, the method including: manufacturing the power module by injecting molding resin into a molding die in a state where the adjusting member is expanded or contracted by the molding die and adjusts the distance to an intended distance.

Yet another embodiment of the present invention provides a molding die used for manufacturing a power module including a semiconductor element, a first cooling member and a second cooling member configured to sandwich the semiconductor element therebetween, a frame member configured to support the semiconductor element between the first cooling member and the second cooling member and configured to include an adjusting member which adjusts a distance between the first cooling member and the second cooling member, and a molded resin disposed between the first cooling member and the second cooling member, the molding die including: a first molding body configured to hold the first cooling member during a molding process of the molded resin; a second molding body configured to hold the second cooling member during the molding process; a first pressing pin configured to extend from a side of the first molding body and to press a second metal block disposed on a side of the second cooling member; and a second pressing pin configured to extend from a side of the second molding body and to press a first metal block disposed on a side of the first cooling member, and wherein the elastic member is expanded by the first metal block which is being pressed by the second pressing pin, and by the second metal block which is being pressed by the first pressing pin during the molding process.

Other objects, features and advantages of the embodiments of the present invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view of a power module according to a first embodiment of the present invention;

FIG. **2** is a cross-sectional view of the power module and a molding die of the first embodiment;

FIG. **3**A is a cross-sectional view of the power module and the molding die taken along a line A-A illustrated in FIG. **2**;

FIG. **3**B is a cross-sectional view of the power module and the molding die taken along a line B-B illustrated in FIG. **2**;

FIG. **4** is a cross-sectional view of a power module according to an exemplary variation of the first embodiment of the present invention;

FIG. **5** is a cross-sectional view of a power module according to another exemplary variation of the first embodiment of the present invention;

FIG. **6** is a cross-sectional view of a power module according to another exemplary variation of the first embodiment of the present invention;

FIG. **7** is a cross-sectional view of a power module inserted between a molding die according to a second embodiment of the present invention;

FIG. **8** illustrates a block member included in a frame member of the power module **400** of the second embodiment;

FIG. **9** is a cross-sectional view of a power module according to an exemplary variation of the second embodiment of the present invention;

FIG. **10** is a cross-sectional view of a power module according to another exemplary variation of the second embodiment of the present invention; and

FIG. **11** is a cross-sectional view of a power module according to yet another exemplary variation of the embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, embodiments of a power module, a method for manufacturing the power module and a molding die used for molding the power module of the present invention will be described by referring to the accompanying drawings.

First Embodiment

FIG. **1** is a cross-sectional view of a power module **10** according to a first embodiment of the present invention. FIG. **1** illustrates a cross sectional view of the power module **10**. The power module **10** according to the present embodiment is a type of a module which is included in an inverter or a voltage up/down converter which is disposed between a direct-current power source and an electric motor of a hybrid vehicle or an electric vehicle, for example.

As illustrated in FIG. **1**, the power module **10** includes six semiconductor elements **12**A and **12**B, for example. The semiconductor elements **12**A and **12**B are switching elements such as Insulated Gate Bipolar Transistors (IGBTs) or the like and diodes, for example, and constitute upper arm units and lower arm units of the inverter or the voltage up/down converter. Switching operation of the switching elements are performed so that the switching elements output currents flowing through U-phase, V-phase and W-phase of the electric motor and perform stepping up and down control. The semiconductor elements **12**A and **12**B are connected to external terminals via bonding wires (not illustrated). Signals are supplied to the semiconductor elements **12** through the bonding wires from an external control device, and signals are output from the semiconductor elements **12**A and **12**B to the external control device via the bonding wires.

The power module **10** includes metal blocks **14**A, **14**B, **14**C, **14**D and **14**E that are disposed close to the semiconductor elements **12**A and **12**B. The metal blocks **14**A, **14**B, **14**C, **14**D and **14**E are made of metal having high heat transfer performance such as copper. The metal blocks **14**A to **14**E function as radiator plates (heat sinks) that enhance heat transfer performance of the semiconductor elements **12**A and **12**B and as back wirings. The metal blocks **14**A and **14**B have relatively large surface areas, and the metal blocks **14**C, **14**D and **14**E have relatively small surface areas. The metal blocks **14**A to **14**E have designated shapes, respectively.

The metal blocks **14**A and **14**B having relatively large surface areas are disposed at a designated distance and opposed with each other. The metal blocks **14**C, **14**D and **14**E having relatively small surface areas are arranged in parallel to each other between the metal blocks **14**A and **14**B. The metal blocks **14**C, **14**D and **14**E are disposed almost in the middle of the metal blocks **14**A and **14**B and are opposed to the metal blocks **14**A and **14**B at designated distances. The three semiconductor elements **12**A are disposed between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E, respectively. The other three semiconductor elements **12**B are disposed between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E, respectively.

Three pairs of the semiconductor elements **12**A and **12**B are stacked vertically between the metal blocks **14**A and **14**B. Each pair of the semiconductor elements **12**A and **12**B is disposed and electrically connected in series between the metal blocks **14**A and **14**B. According to the configuration as described above, a mounting area in which the semiconductor elements **12**A and **12**B are disposed becomes smaller than a mounting area in which six semiconductor elements that constitute upper and lower arm units of the inverter are disposed in the same level. Thus the power module **10** is downsized. Three pairs of the semiconductor elements **12**A and **12**B are disposed in parallel with each other between the metal blocks **14**A and **14**B. Each pair of the semiconductor elements **12**A and **12**B is disposed in series between the metal blocks **14**A and **14**B. The upper three semiconductor elements **12**A are disposed between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E, respectively. The lower three semiconductor elements **12**B are disposed between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E, respectively.

The power module **10** includes six frame members **16**. The upper three frame members **16** support the semiconductor elements **12**A between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E, respectively. The lower three frame members **16** support the semiconductor elements **12**B between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E, respectively. The semiconductor elements **12**A are supported between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E, respectively. The semiconductor elements **12**B are supported between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E, respectively. The semiconductor elements **12**A are connected to the upper surfaces of the metal blocks **14**C, **14**D, and **14**E by solders **18**, respectively. The semiconductor elements **12**B are connected to the upper surface of the metal block **14**B by solders **18**, respectively. The semiconductor elements **12**A are connected to the upper surfaces of the metal blocks **14**C, **14**D and **14**E via the solders **18**. The semiconductor elements **12**B are connected to the upper surface of the metal block **14**B. The lower surfaces of the upper three semiconductor elements **12**A are connected to the upper surfaces of the metal blocks **14**C, **14**D and **14**E via the solders **18**. The upper surfaces of the upper three semiconductor elements **12**A are connected to the lower surface of the metal block **14**A via the solders **22**, the spring members **20**A and the solders **24**. The lower surfaces of the upper three semiconductor elements **12**B are connected to the upper surfaces of the metal block **14**B via the solders **18**. The upper surfaces of the upper three semiconductor elements **12**B are connected to the lower surface of the metal blocks **14**C, **14**D and **14**E via the solders **22**, the spring members **20**B and the solders **24**.

Each of the three spring members **20**A constitutes a part of each of the three upper frame members **16**. Each of the three spring members **20**B constitutes a part of each of the three lower frame members **16**. Accordingly, the upper three frame members **16** include the spring members **20**A. The lower three frame members **16** include the spring members **20**B. The spring members **20**A and **20**B have elasticity. The spring

members **20**A and **20**B are connected in series between the metal blocks **14**A and **14**B. The spring members **20**A and **20**B are made of a metallic material having a heat transfer performance and conductivity such as copper or the like, for example.

The spring members **20**A and **20**B are type of elastic members that can expand and/or contract between the metal blocks **14**A and **14**B in a direction in which the metal blocks **14**A and **14**B face with each other. I.e., the spring members **20**A and **20**B can expand and/or contract between cooling blocks **26**A and **26**B in a direction in which the metal blocks **14**A, **14**B, **14**C, **14**D and **14**E, the blocks **26**A and **26**B, and the semiconductor elements **12**A and **12**B are stacked with each other. The spring members **20**A and **20**B have configurations that are obtained by bending plates in U-shape or configurations of plate springs. The blocks **26**A and **26**B will be described later. In order to enhance the heat transfer performance and/or the conductivity of the spring members **20**A and **20**B, solders or the like may be supplied in the U-shaped spring.

Lower ends of the spring members **20**A are connected to the semiconductor elements **12**A via the solders **22**. Lower ends of the spring members **20**B are connected to the semiconductor elements **12**B via the solders **22**. Upper ends of the upper three spring members **20**A are connected to the metal block **14**A via the solders **24**. Upper ends of the lower three spring members **20**B are connected to the metal blocks **14**C, **14**D and **14**E via the solders **24**, respectively. The spring members **20**A and **20**B can adjust distances between the semiconductor elements **12**A and **12**B and the metal blocks **14**A, **14**B, **14**C, **14**D and **14**E. Distances between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E can be adjusted by expansion or contraction the spring members **20**A. Distances between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E can be adjusted by expansion or contraction of the spring members **20**B.

The cooling block **26**A is disposed onto the metal block **14**A, and the cooling block **26**B is disposed under the metal block **14**B. The cooling blocks **26**A and **26**B are made of metal having high thermal conductivity such as aluminum or the like. The cooling blocks **26**A and **26**B have functions of conducting heat conducted from the metal blocks **14**A and **14**B to cooling medium such as the air by performing heat exchange. The spring members **20**A are disposed between the semiconductor elements **12**A and the cooling block **26**A. The spring members **20**A are thermally, mechanically and electrically connected to the semiconductor elements **12**A and the cooling block **26**A. The spring members **20**B are disposed between the semiconductor elements **12**B and the metal blocks **14**C, **14**D and **14**E. The spring members **20**B are thermally, mechanically and electrically connected to the semiconductor elements **12**B and the cooling block **26**B.

The power module **10** has a configuration in which the semiconductor elements **12**A and **12**B are sandwiched by the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B. In this configuration, the heat generated by the semiconductor elements **12**A and **12**B is conducted to the cooling blocks **26**A and **26**B that are disposed on both ends of the power module **10**. Thus, it becomes possible to improve cooling performance of the power module **10** compared with a comparative power module which has one cooling block disposed only on one end of the comparative power module.

Cooling fins **28** are disposed on the outer surfaces of the cooling blocks **26**A and **26**B. The cooling fins **28** project outwardly from the outer surfaces of the cooling blocks **26**A and **26**B. Each of the cooling fins **28** is a type of a member which enhances heat exchange between the cooling block **26**A or **26**B and the cooling medium.

Insulating members **30** are inserted between the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B, respectively. The insulating members **30** may be insulating sheets made of resin, for example. The insulating members **30** insulate the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B, respectively. It is preferable that the insulating members **30** have higher thermal conductivity than molded resin **32** which will be described later. The power module **10** has a configuration in which the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the spring members **20**A and **20**B and the insulating members **30** are stacked between the cooling blocks **26**A and **26**B.

The power module **10** includes the molded resin **32** which is supplied between the cooling blocks **26**A and **26**B. The molded resin **32** seals the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the spring members **20** and the insulating members **30** between the cooling blocks **26**A and **26**B. The molded resin **32** is made of an epoxy resin, for example. The outer surfaces of the cooling blocks **26**A and **26**B are exposed from the molded resin **32**. Accordingly, the molded resin **32** does not cover the outer surfaces of the cooling members **26**A and **26**B. When the power module **10** is manufactured, the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the spring members **20**, the insulating members **30** and the cooling blocks **26**A and **26**B are stacked and held in a molding die **34** which will be described later. And then the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the spring members **20**A and **20**B, the insulating members **30** and the cooling blocks **26**A and **26**B are molded by resin which becomes the molded resin **32**.

In the followings, the manufacturing process of the power module **10** of the present embodiment will be described with regard to FIGS. **2**, **3**A and **3**B. FIG. **2** is a cross-sectional view of the power module **10** and the molding die **34** of the present embodiment. FIG. **3**A is a cross-sectional view of the power module **10** and the molding die **34** taken along a line A-A illustrated in FIG. **2**. FIG. **3**B is a cross-sectional view of the power module **10** and the molding die **34** taken along a line B-B illustrated in FIG. **2**.

In the present embodiment, the power module **10** is manufactured by using the molding die **34**. The molding die **34** has inner dimensions that meet the outer shape of the power module **10** which becomes the final product. Before the molded resin **32** is formed, distance between the outer surfaces of the cooling blocks **26**A and **26**B (i.e., between the upper surface of the cooling block **26**A and the lower surface of the cooling block **26**B) sandwiching the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the spring members **20** and the insulating members **30** is shorter than corresponding distance (an intended length) of the power module **10** after being molded by the molded resin **32**. In other words, the distance between the outer surfaces of the cooling blocks **26**A and **26**B before being molded by the molded resin **32** is shorter than corresponding distance (the intended length) of the power module **10** when the power module **10** is completed as the final product. When the power module **10** is completed, the distance is equal to an inner dimension of the molding die **34**. Before being molded by the molded resin **32**, natural lengths of the spring members **20**A and **20**B in a stack direction are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B shorter than corresponding distance of the power module **10** after being molded by the molded resin **32**.

Hereinafter, a structural body in which the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the spring members **20**A and **20**B and the insulating members **30** are sandwiched between the cooling blocks **26**A and **26**B before being molded by the molded resin **32** is referred to as a structural body **40**.

The molding die **34** is separated into upper molding die **34**A and lower molding die **34**B. The upper molding die **34**A and the lower molding die **34**B are put together along a parting line L. The upper molding die **34**A includes an upper body **34**A-**1** and upper pressing pins **34**A-**2**. The upper body **34**A-**1** contacts the outer surface of the cooling block **26**A and holds the cooling block **26**A. The upper pressing pins **34**A-**2** extend from the inner surface of the upper body **34**A-**1** toward the cooling block **26**B or the metal block **14**B which is held by the lower molding die **34**B. The lower molding die **34**B includes a lower body **34**B-**1** and lower pressing pins **34**B-**2**. The lower body **34**B-**1** contacts the outer surface of the cooling block **26**B and holds the cooling block **26**B. The lower pressing pins **34**A-**2** extend from the inner surface of the lower body **34**B-**1** toward the cooling block **26**A or the metal block **14**A which is held by the upper molding die **34**A.

The upper pressing pins **34**A-**2** have lengths longer than length between the outer surface of the cooling block **26**A and the upper surface of the metal block **14**B of the structural body **40** in a state where the lengths of the spring members **20** are the natural lengths. More specifically, the upper pressing pins **34**A-**2** have the lengths that are almost the same as distance between the outer surface of the cooling block **26**A and the upper surface of the metal block **14**B of the power module **10** when the power module **10** is completed as the final product.

The lower pressing pins **34**B-**2** have lengths longer than length between the outer surface of the cooling block **26**B and the lower surface of the metal block **14**A of the structural body **40** in a state where the lengths of the spring members **20** are the natural lengths. More specifically, the lower pressing pins **34**B-**2** have the lengths that are almost the same as distance between the outer surface of the cooling block **26**B and the lower surface of the metal block **14**A of the power module **10** when the power module **10** is completed as the final product.

The pressing pins **34**A-**2** have function of pressing the metal block **14**B disposed on the opposite side. The pressing pins **34**B-**2** have function of pressing the metal block **14**A disposed on the opposite side. More specifically, the pressing pins **34**A-**2** and **34**B-**2** have functions of expanding the spring members **20** outwardly by pressing the metal blocks **14**B and **14**A, respectively.

As illustrated in FIGS. **3**A and **3**B, in the power module **10**, each of the cooling blocks **26**A and **26**B has an opposed surface. The opposed surfaces of the cooling blocks **26**A and **26**B have almost the same areas and almost the same shapes and sizes. Each of the metal blocks **14**A and **14**B has an opposed surface. The opposed surfaces of the metal blocks **14**A and **14**B have different shapes and sizes with each other. For example, as illustrated in FIG. **3**A, the metal block **14**A has an elongated shape compared with the metal block **14**B as illustrated in FIG. **3**B. Length of the metal block **14**A in the longitudinal direction in plan view is longer than that of the metal block **14**B. Length of the metal block **14**B in the direction vertical to the longitudinal direction in plan view is longer than that of the metal block **14**A.

The opposed surfaces of the metal blocks **14**A and **14**B are smaller than the opposed surfaces of the cooling blocks **26**A and **26**B. The insulating members **30** are slightly larger than the metal blocks **14**A and **14**B in plan view. Accordingly, opposed surfaces of the insulating members **30** are larger than the opposed surfaces of the metal blocks **14**A and **14**B.

The cooling block **26**A has through holes **36**A. The upper pressing pins **34**A-**2** of the upper molding die **34**A are inserted through the through holes **36**A, respectively. The through holes **36**A are formed in positions of the cooling block **26**A that are located outside of an area opposing to the metal block **14**A and are located in an area opposing to the metal block **14**B, in plan view. The cooling block **26**B has through holes **36**B. The lower pressing pins **34**B-**2** of the lower molding die **34**B are inserted through the through holes **36**B, respectively. The through holes **36**B are formed in positions of the cooling block **26**B that are located outside of an area opposing to the metal block **14**B and are located in an area opposing to the metal block **14**A, in plan view.

The through holes **36**A are located in positions where the through holes **36**A do not overlap with the metal block **14**A which is stacked with the cooling block **26**A, but overlap with the metal block **14**B which is stacked with the cooling block **26**B. The through holes **36**B are located in positions where the through holes **36**B do not overlap with the metal block **14**B which is stacked with the cooling block **26**B, but overlap with the metal block **14**A which is stacked with the cooling block **26**A. The through holes **36**A and **36**B extend in the direction vertical to the surfaces of the cooling blocks **26**A and **26**B and the surfaces of the metal blocks **14**A and **14**B, i.e. in the vertical direction as illustrated in FIG. **1**. The metal blocks **14**A and **14**B are designed to have sizes that meet the positions of the cooling blocks **26**A and **26**B and the through holes **36**A and **36**B.

In the manufacturing process of the power module **10**, before the molded resin **32** is being molded, the three semiconductor elements **12**A are soldered on the metal blocks **14**C to **14**E by the solders **18**, respectively, and the other three semiconductor elements **12**B are soldered on the metal block **14**B by the solders **18**. The three spring members **20**A are soldered on the metal block **14**A by the solders **24**, respectively, and the other three spring members **20**B are soldered on the metal blocks **14**C to **14**E by the solders **24**, respectively. Then the semiconductor elements **12**A and **12**B and the spring members **20**A and **20**B are connected by the solders **22**. Next, the insulating members **30** are temporarily fixed between the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B, respectively. Thus, the structural body **40** in which the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the spring members **20**A and **20**B and the insulating members **30** are sandwiched between the cooling blocks **26**A and **26**B is completed. Then the structural body **40** in which the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the spring members **20**A and **20**B and the insulating members **30** are sandwiched between the cooling blocks **26**A and **26**B is inserted into the molding die **34** and held by the molding die **34**.

As described above, in the structural body **40**, the distance between the outer surfaces of the cooling blocks **26**A and **26**B in a state where the lengths of the spring members **20**A and **20**B are the natural lengths is shorter than the corresponding inner length of the molding die **34**. The lengths of the upper pressing pins **34**A-**2** are longer than the distance between the outer surface of the cooling block **26**A and the upper surface of the metal block **14**B in a state where the lengths of the spring members **20**A and **20**B are the natural lengths in the structural body **40**. And the lengths of the upper pressing pins **34**A-**2** are almost the same as the distance between the outer surface of the cooling block **26**A and the upper surface of the metal block **14**B when the power module **10** is completed as

the final product. The lengths of the lower pressing pins **34**B-**2** are longer than the distance between the outer surface of the cooling block **26**B and the lower surface of the metal block **14**A in a state where the lengths of the spring members **20**A and **20**B are the natural lengths in the structural body **40**. And the lengths of the lower pressing pins **34**B-**2** are almost the same as the distance between the outer surface of the cooling block **26**B and the lower surface of the metal block **14**A when the power module **10** is completed as the final product.

When the upper pressing pins **34**A-**2** of the upper molding die **34**A are inserted into the through holes **36**A of the cooling block **26**A of the structural body **40** in a condition where the upper body **34**A-**1** of the upper molding die **34**A contacts with the outer surface of the cooling block **26**A of the structural body **40**, the upper pressing pins **34**A-**2** contact with the upper surface of the metal block **14**B. In this condition, the upper pressing pins **34**A-**2** press the upper surface of the metal block **14**B downwardly, i.e. in the direction from the metal block **14**B to the cooling block **26**B which contacts with the metal block **14**B via the insulating member **30**.

When the lower pressing pins **34**B-**2** of the lower molding die **34**B are inserted into the through holes **36**B of the cooling block **26**B of the structural body **40** in a condition where the lower body **34**B-**1** of the lower molding die **34**B contacts with the outer surface of the cooling block **26**B of the structural body **40**, the lower pressing pins **34**B-**2** contact with the lower surface of the metal block **14**A. In this condition, the lower pressing pins **34**B-**2** press the lower surface of the metal block **14**A upwardly, i.e. in the direction from the metal block **14**A to the cooling block **26**A which contacts with the metal block **14**A via the insulating member **30**.

When the upper molding die **34**A and the lower molding die **34**B are put together along the parting line L, the upper pressing pins **34**A-**2** press the metal block **14**B which is located in the lower side of the structural body **40** downwardly, and at the same time, the lower pressing pins **34**B-**2** press the metal block **14**A which is located in the upper side of the structural body **40** upwardly.

The spring members **20**A and **20**B included in the frame members **16** of the structural body **40** can expand and contract in the vertical direction as illustrated in FIG. **1**, i.e. the direction in which the metal blocks **14**A and **14**B face with each other. When the upper pressing pins **34**A-**2** press the metal block **14**B and the lower pressing pins **34**B-**2** press the metal block **14**A as the upper molding die **34**A and the lower molding die **34**B are put together along the parting line L, the spring members **20**A and **20**B are deformed and expanded in the vertical direction compared with the natural lengths in a condition where the cooling blocks **26**A and **26**B are held by the upper body **34**A-**1** of the upper molding die **34**A and the lower body **34**B-**1** of the lower molding die **34**B, respectively.

As the spring members **20**A and **20**B are deformed as described above, the distance between the outer surfaces of the cooling blocks **26**A and **26**B of the structural body **40** corresponds to the inner dimension of the molding die **34**, i.e. the distance between the outer surfaces of the cooling blocks **26**A and **26**B of the structural body **40** becomes equal to a distance (the intended length) which is conclusively required between the outer surfaces of the cooling blocks **26**A and **26**B of the power module **10**. In this condition, thickness of the structural body **40** becomes greater than that of the structural body **40** when the lengths of the spring members **20**A and **20**B are the natural lengths.

In a condition where the structural body **40** is held by the molding die **34** as described above, molding resin is injected into the molding die **34** at a designated molding pressure. The molding resin is a resin material which is used for forming the molded resin **32**. By injecting the molding resin into the molding die **34**, the molding resin is supplied between the cooling blocks **26**A and **26**B that are expanded by the upper pressing pins **34**A-**2** and **34**B-**2** via the metal blocks **14**A and **14**B, respectively. The molding resin becomes the molded resin **32** formed between the cooling blocks **26**A and **26**B. Accordingly, the power module **10** is completed. Finally, the upper pressing pins **34**A-**2** and the lower pressing pins **34**B-**2** of the molding die **34** are withdrawn from the through holes **36**A and **36**B of the cooling block **26**A and **26**B, respectively, and the power module **10** is picked up from the molding die **34**.

Accordingly, it becomes possible to manufacture the power module **10** which has the intended length by supplying the molding resin into the molding die **34** in a state where the spring members **20**A and **20**B included in the structural body **40** between the cooling blocks **26**A and **26**B are expanded by the molding die **34**. The spring members **20**A and **20**B are expanded in a state where the structural body **40** is inserted into the molding die **34** in the stack direction, i.e. the direction in which the metal blocks **14**A and **14**B face with each other (the vertical direction as illustrated in FIG. **1**). The spring members **20**A and **20**B are included in the frame members **16**.

According to the present embodiment, it is possible to absorb the dimensional tolerance of the power module **10** by utilizing the spring members **20**A and **20**B included in frame members **16** of the power module **10** and the molding die **34** including the upper pressing pins **34**A-**2** and the lower pressing pins **34**B-**2**. Thus, it becomes possible to realize the dimensional management of the power module **10** in which the molded resin **32** is supplied between the cooling blocks **26**A and **26**B sandwiching the semiconductor elements **12**A and **12**B. Therefore, it becomes possible to suppress leakage of the molding resin from the molding die **34** and breakage of the semiconductor elements **12**A and **12**B or the like by the molding pressure during the molding process. Further, it is not necessary to inject extra molding resin into the molding die **32** during the molding process and to remove an excess portion of the molded resin **32** after adjusting the intended length.

In the present embodiment as described above, the upper pressing pins **34**A-**2** of the upper molding die **34**A press the metal block **14**B which is located lower side of the structural body **40** downwardly, and the lower pressing pins **34**B-**2** of the lower molding die **34**B press the metal block **14**A which is located upper side of the structural body **40** upwardly during the molding process. In other words, the upper pressing pins **34**A-**2** generate forces that press the metal block **14**B downwardly, and the lower pressing pins **34**B-**2** generate forces that press the metal block **14**A upwardly. In this condition, since the metal block **14**B is pressed to a side of the cooling block **26**B, the insulating member **30** disposed between the metal block **14**B and the cooling block **26**B is in close contact with and is sandwiched between the metal block **14**B and the cooling block **26**B. Since the metal block **14**A is pressed to a side of the cooling block **26**A, the insulating member **30** disposed between the metal block **14**A and the cooling block **26**A is in close contact with and is sandwiched between the metal block **14**A and the cooling block **26**A.

And then the molded resin **32** is formed between the cooling blocks **26**A and **26**B by injecting the molding resin therebetween in a state where the insulating members **30** are sandwiched between the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B, respectively. According to the present embodiment, it is possible to fix the both surfaces of

the insulating members **30** to the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B, respectively by the molding pressure.

In the first embodiment as described above, the cooling block **26**A is one example of a first cooling member, and the cooling block **26**B is one example of a second cooling member. Herein, the first cooling member may include the cooling fins **28**, the second cooling member may include the cooling fins **28**. Each of the spring members **20**A and **20**B is one example of a spring member and an elastic member. The upper body **34**A-**1** is one example of a first molding body, and the lower body **34**B-**1** is one example of a second molding body. Each of the upper pressing pins **34**A-**2** is one example of a first pressing pin, and each of the lower pressing pins **34**B-**2** is one example of a second pressing pin. The molding die **34** is one example of a molding die used for manufacturing a power module.

Although the upper pressing pins **34**A-**2** and the lower pressing pins **34**B-**2** are connected to the upper body **34**A-**1** and the lower body **34**B-**1**, respectively, and the upper pressing pins **34**A-**2** and the lower pressing pins **34**B-**2** extend toward the cooling blocks **26**B and **26**A (or the metal blocks **14**B and **14**A), respectively, the scope of the present invention is not limited to the configuration as described above.

As illustrated in FIG. **4**, a molding die **102** may include an upper body **102**A, a lower body **102**B, upper pressing pins **104**A and lower pressing pins **104**B. The upper pressing pins **104**A and the lower pressing pins **104**B are separated from the upper body **102**A and the lower body **102**B, respectively. The upper pressing pins **104**A extend toward the cooling block **26**B (or the metal block **14**B) from the upper body **102**A, and the lower pressing pins **104**B extend toward the cooling block **26**A (or the metal block **14**A) from the lower body **102**B. The upper pressing pins **104**A press the metal block **14**B downwardly, and the lower pressing pins **104**B press the metal block **14**A upwardly during the molding process of a power module **100**. In this exemplary variation, the upper pressing pins **104**A and the lower pressing pins **104**B may be expanded or contracted by a displace machine between positions for pressing the metal blocks **14**A and **14**B, respectively, and positions for releasing the metal blocks **14**A and **14**B.

In this exemplary variation, since the upper pressing pins **104**A and the lower pressing pins **104**B are separated from the upper body **102**A and the lower body **102**B, respectively, the upper pressing pins **104**A and the lower pressing pins **104** can be withdrawn before removing the upper body **102**A and the lower body **102**B from the power module **100** when the power module **100** is completed. Therefore, according to the exemplary variation as described above, it becomes possible to suppress breakage of the molded resin **32** that may be caused when the upper pressing pins **104**A and the lower pressing pins **104**B are withdrawn from the upper body **102**A and the lower body **102**B, respectively. This is different from the embodiment in that the molding die **34** having the upper pressing pins **34**A-**2** and the lower pressing pins **34**B-**2** that are unified with the upper body **34**A-**1** and the lower body **34**B-**1**, respectively, is removed from the power module **10**.

In this exemplary variation, it is not necessary for forming through holes for inserting the upper pressing pins **104**A and the lower pressing pins **104**B therethrough in the cooling blocks **26**A and **26**B. The upper pressing pins **104**A and the lower pressing pins **104**B may be inserted into the through holes that are formed obliquely on the side walls of the molding die **34**. The upper pressing pins **104**A and the lower pressing pins **104**B can be expanded or contracted through the through holes formed obliquely on the side walls of the molding die **34** by the displace machine. In this configuration, the upper pressing pins **104**A and the lower pressing pins **104**B contact with the upper surface of the metal block **14**B and the lower surface of the metal block **14**A obliquely, respectively. Although holes that are formed by insertion of the upper pressing pins **104**A and the lower pressing pins **104**B remain on the side walls of the molded resin **32** of the power module **100**, insulating performance and cooling performance of the power module **100** are not affected by the holes formed on the side walls of the molded resin **32**. Thus, it is not necessary to cover the holes after completion of the power module **100**.

According to the embodiment as illustrated in FIGS. **1** to **3**, the upper pressing pins **34**A-**2** and the lower pressing pins **34**B-**2** extend vertical to the upper surface of the metal block **14**B and the lower surface of the metal block **14**A, respectively. Thus, the sizes of the metal blocks **14**A and **14**B are different from each other. On the contrary, the exemplary variation as described above is different from the embodiment as described with regard to FIGS. **1** to **3** in that the upper pressing pins **104**A and the lower pressing pins **104**B extend obliquely toward the upper surface of the metal block **14**B and the lower surface of the metal block **14**A. Thus, according to the exemplary variation as illustrated in FIG. **4**, it becomes possible to commonalize the sizes of the metal blocks **14**A and **14**B. Further, it becomes possible to enhance use of space in the power module **100** and to suppress increase of manufacturing steps.

As described above, before the power module **10** is completed, the natural lengths of the spring members **20**A and **20**B in the stack direction are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B shorter than corresponding distance of the power module **10** when the power module **10** is completed as the final product. The distance between the outer surfaces of the cooling blocks **26**A and **26**B is expanded to the designated distance (the intended length) in the stack direction and kept to the designated distance by the molding die **34** during the manufacturing process. The present invention is not limited to the embodiment as described above.

As illustrated in FIG. **5**, before a power module **200** is completed, natural lengths of spring members **202**A and **202**B in the stack direction are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B longer than corresponding distance of the power module **200** when the power module **200** is completed as the final product. The distance between the outer surfaces of the cooling blocks **26**A and **26**B is contracted to the designated distance (the intended length) by being pressed by the molding die **204**.

In the exemplary variation as illustrated in FIG. **5**, it becomes possible to manufacture the power module **200** which has the intended length by supplying the molding resin into the molding die **204** in a state where the spring members **202**A **202**B disposed between the cooling blocks **26**A and **26**B are contracted by being pressed in the molding die **204**. The spring members **202**A and **202**B are contracted in a state where the spring members **202**A and **202**B are being inserted into the molding die **204**.

Thus, similar advantageous effects to those of the embodiments as illustrated in FIGS. **1** to **3** can be obtained according to the exemplary variation as illustrated in FIG. **5**. When an upper molding die **204**A and a lower molding die **204**B of the molding die **204** are put together along a parting line L during the molding process of the power module **200**, the insulating members **30** are in close contact with and are sandwiched between the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B, respectively, by pressing forces generated in the molding die **204**. Thus, it is possible to fix the surfaces of

the insulating members **30** to the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B, respectively. In the exemplary variation as illustrated in FIG. **5**, it is not necessary to dispose pressing pins such as the upper pressing pins **34**A-**2** and the lower pressing pins **34**B-**2** in the molding die **204**. Thus, no holes remain in the molded resin **32** and the cooling blocks **26**A and **26**B of the power module **200**.

As described in the first embodiment, the spring members **20**A and **20**B that can expand and contract in the stack direction between the metal blocks **14**A and **14**B are disposed as a part of the respective frame members **16** that are disposed between the cooling blocks **26**A and **26**B. However, the present embodiment is not limited to the embodiment as described above. Conductive resins **306**A and **306**B may be used instead of the spring members **20**A and **20**B as illustrated in FIG. **6**. In this case, the conductive resins **306**A and **306**B having high heat transfer performance are included in frame members **302** disposed between the cooling blocks **26**A and **26**B. The conductive resins **306**A and **306**B can be expanded and contracted in the stack direction of the semiconductor elements **12**A and **12**B and the cooling blocks **26**A and **26**B by being pressed or pulled in a molding die **304** during the molding process of a power module **300**.

The conductive resins **306**A are disposed between the semiconductor elements **12**A and the metal block **14**A. The conductive resins **306**B are disposed between the semiconductor elements **12**B and the metal blocks **14**C, **14**D and **14**E. The conductive resins **306**A are disposed between the semiconductor elements **12**A and the metal blocks **14**A (i.e., between the semiconductor elements **12**A and the cooling block **26**A). The conductive resins **306**B are disposed between the semiconductor elements **12**B and the metal blocks **14**C, **14**D and **14**E. For example, the conductive resins **306**A and **306**B are made of epoxy resin including conductive fillers or conductive polymers. The conductive resins **306**A and **306**B are formed in block shapes. The conductive resins **306**A and **306**B have elasticity and can expand and contract in the stack direction. The conductive resins **306**A and **306**B have higher heat transfer performance than the spring members **20**A and **20**B as described above.

Lower ends of the conductive resins **306**A are connected to the semiconductor elements **12**A via the solders **22**. Lower ends of the conductive resins **306**B are connected to the semiconductor elements **12**B via the solders **22**. Upper ends of the conductive resins **306**A are connected to the metal block **14**A via the solders **24**. Upper ends of the conductive resins **306**B are connected to the metal blocks **14**C, **14**D and **14**E via the solders **24**, respectively. Distances between the semiconductor elements **12**A and **12**B and the metal blocks **14**A, **14**B, **14**C, **14**D and **14**E can be adjusted by the conductive resins **306**A and **306**B. Distances between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E can be adjusted by expansion or contraction of the conductive resins **306**A. Distances between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E can be adjusted by expansion or contraction of the conductive resins **306**B.

Before being molded by the molded resin **32**, natural lengths of the conductive resins **306**A and **306**B in the stack direction are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B longer than corresponding distance of the power module **300** after being molded by the molded resin **32**.

In the exemplary variation as illustrated in FIG. **6**, it becomes possible to manufacture the power module **300** which has the intended length by supplying the molding resin into the molding die **304** in a state where the conductive resins **306**A and **306**B disposed between the cooling blocks **26**A and **26**B are contracted by being pressed in the molding die **304**. The conductive resins **306**A and **306**B are contracted in a state where the conductive resins **306**A and **306**B are inserted into the molding die **304**. The intended length is equal to an inner dimension of the molding die **34**. Thus, similar advantageous effects to those of the embodiments as illustrated in FIGS. **1** to **5** can be obtained according to the exemplary variation as illustrated in FIG. **6**. According to the exemplary variation as illustrated in FIG. **6**, as described above, the conductive resins **306**A and **306**B have higher heat transfer performance than the spring members **20**A and **20**B. Accordingly, it becomes possible to improve the heat transfer performance between the semiconductor elements **12**A and cooling block **26**A and between the semiconductor elements **12**B and the cooling block **26**B.

In this exemplary variation as illustrated in FIG. **6**, before being molded by the molded resin **32**, the natural lengths of the conductive resins **306**A and **306**B in the stack direction are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B longer than the corresponding distance of the power module **300** after being molded by the molded resin **32**. The natural lengths of the conductive resins **306**A and **306**B in the stack direction, before being molded by the molded resin **32**, are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B shorter than the corresponding distance of the power module **300** after being molded by the molded resin **32**. Accordingly, in the exemplary variation as illustrated in FIG. **6**, the distance between the outer surfaces of the cooling members **26**A and **26**B are adjusted to the intended length by causing the molding die **304** to pull or press the conductive resins **306**A and **306**B in the stack direction when the power module **300** is being molded.

Second Embodiment

FIG. **7** is a cross-sectional view of a power module **400** inserted between parts of a molding die **408** according to a second embodiment of the present invention. In FIG. **7**, the same elements as or elements similar to those of the power modules **10**, **100**, **200** and **300** as illustrated in FIGS. **1** to **6** are referred to by the same reference numerals, and a description thereof is omitted or simplified. FIG. **8** illustrates block members **404** included in a frame member **402** of the power module **400** of the second embodiment. As illustrated in FIG. **7**, the power module **400** includes block members **404**A and **404**B. The block members **404**A and **404**B have the same configuration as that of the block member **404** as illustrated in FIG. **8**. Accordingly, the block members **404**A and **404**B may be referred to as the block member **404** in a case where the block members **404**A and **404**B are not distinguished. FIG. part **8** (A) illustrates the block member **404** in a state before causing the molding die **304** to press the block member **404** in the stack direction in order to mold the power module **400**. FIG. part **8** (B) illustrates the block member **404** in a state after causing the molding die **304** to press the block member **404** in the stack direction in order to mold the power module **400**.

In the power module **400**, the upper three frame members **402** support the semiconductor elements **12**A between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E. The lower three frame members **402** support the semiconductor elements **12**B between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E. The lower surfaces of the semiconductor elements **12**A are connected to the upper surfaces of the metal blocks **14**C, **14**D and **14**E via the solders **18**. The upper surfaces of the semiconductor elements **12**A are con-

nected to the lower surface of the metal block **14**A via the frame members **402** including the block members **404**A. The lower surfaces of the semiconductor elements **12**B are connected to the upper surfaces of the metal block **14**B via the solders **18**. The upper surfaces of the semiconductor elements **12**B are connected to the lower surface of the metal blocks **14**C, **14**D and **14**E via the frame members **402** including the block members **404**B.

The three block members **404**A constitute parts of the corresponding three upper frame members **402**. The three block members **404**B constitute parts of the corresponding three lower frame members **402**. The upper three frame members **402** include the block members **404**A between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E, i.e. between the cooling block **26**A and the metal blocks **14**C, **14**D and **14**E. The lower three frame members **402** include the block members **404**B between the metal blocks **14**C, **14**D and **14**E and the metal block **14**B, i.e. between the metal blocks **14**C, **14**D and **14**E and the cooling block **26**B. The block members **404**A and **404**B can adjust their respective heights. The block members **404**A and **404**B are connected in series between the metal blocks **14**A and **14**B. The block members **404**A and **404**B are made of a metallic material having a heat transfer performance and conductivity such as copper or the like, for example. Heat capacities of the block members **404**A and **404**B are greater than those of the spring members **20**A and **20**B of the first embodiment.

Each of the block members **404**A and **404**B includes a multilayered block configuration in which block pieces **406**A, **406**B and **406**C are stacked in the stack direction. The block pieces **406**A, **406**B and **406**C are relatively slidable to each other in a direction orthogonal to the stack direction. Although the three block pieces **406**A, **406**B and **406**C are illustrated in FIG. **8**, the number of the block pieces is not limited to three. The multilayered block configuration may include two or more slidable pieces. Thicknesses of the block pieces **406**A, **406**B and **406**C vary in the direction orthogonal to the stack direction, i.e. the width direction of the block pieces **406**A, **406**B and **406**C. Herein, the thicknesses of the block pieces **406**A, **406**B and **406**C correspond to lengths of the block pieces **406**A, **406**B and **406**C in the stack direction. The thicknesses of the block pieces **406**A and **406**C increase from the left side to the right side as illustrated in FIG. **8**. The thickness of the block piece **406**B increases from the left side to the right side as illustrated in FIG. **8**. The block piece **406**A has an inclined lower surface which contacts with an inclined upper surface of the block piece **406**B. The block piece **406**B has the inclined upper surface which contacts with the inclined lower surface of the block piece **406**A and an inclined lower surface which contacts with an inclined upper surface of the block piece **406**C. The inclined lower surface of the block piece **406**A, the inclined upper and lower surfaces of the block piece **406**B, and the inclined upper surface of the block piece **406**C are inclined with regard to the width direction.

The block pieces **406**A, **406**B and **406**C have shapes that are obtained by slicing a cylindrical metal solid having a flat upper surface and a flat lower surface into three pieces along two inclined surfaces that are inclined with regard to the central axis of the cylindrical metal solid. The perpendicular line of the upper surface of the block piece **406**A extends in the stack direction. The upper surface of the block piece **406**A of the block member **404** is connected to any one of the metal block **14**A, **14**C, **14**D or **14**E via the solder **24**. The perpendicular line of the lower surface of the block piece **406**C extends in the stack direction. The lower surface of the slidable block **406**C of the block member **404** is connected to any one of the semiconductor elements **12**A or **12**B via the solder **22**. The perpendicular line of the lower surface of the block piece **406**A extends in an inclined direction with regard to the stack direction. The perpendicular line of the upper surface of the block piece **406**C extends in an inclined direction with regard to the stack direction.

The perpendicular line of the upper surface of the block piece **406**B extends in an inclined direction with regard to the stack direction. The upper surface of the slidable piece **406**B contacts with the lower surface of the block piece **406**A. The perpendicular line of the lower surface of the block piece **406**B extends in an inclined direction with regard to the stack direction. The lower surface of the slidable piece **406**A contacts with the upper surface of the block piece **406**C. The perpendicular line of the upper surface of the block piece **406**B is not parallel to the perpendicular line of the lower surface of the block piece **406**B. The perpendicular line of the lower surface of the block piece **406**A is not parallel to the perpendicular line of the upper surface of the block piece **406**C. The perpendicular line of the lower surface of the block piece **406**A is almost parallel to the perpendicular line of the upper surface of the block piece **406**B. The perpendicular line of the lower surface of the block piece **406**B is almost parallel to the perpendicular line of the upper surface of the block piece **406**C.

The block piece **406**B is slidable in the width direction with regard to the block pieces **406**A and **406**C. The block pieces **406**A and **406**C are relatively slidable with regard to the block piece **406**B as illustrated in FIG. part **8** (B). As illustrated in FIG. **8**, the block pieces **406**A and **406**C are relatively slidable in the width direction with regard to the block piece **406**B. The block piece **406**B is slidable in the width direction with regard to the block pieces **406**A and **406**C. The block pieces **406**A, **406**B and **406**C relatively slide with each other in the width direction in a state where the block pieces **406**A, **406**B and **406**C are pressed in the stack direction. As the block piece **406**B slides in the width direction with regard to the block pieces **406**A and **406**C when the block pieces **406**A, **406**B and **406**C are being pressed in the stack direction, the height of the block member **404**A varies. The same applies to the block member **404**B.

Lower ends of the block members **404**A are connected to the semiconductor elements **12**A via the solders **22**. Lower ends of the block members **404**B are connected to the semiconductor elements **12**B via the solders **22**. Upper ends of the block members **404**A are connected to the metal block **14**A via the solders **24**. Upper ends of the block members **404**B are connected to the metal blocks **14**C, **14**D and **14**E via the solders **24**, respectively. Distances between the semiconductor elements **12**A and **12**B and the metal blocks **14**A, **14**B, **14**C, **14**D and **14**E can be adjusted by the block members **404**A and **404**B. Distances between the metal block **14**A and the metal blocks **14**C, **14**D and **14**E can be adjusted by exemplary variations of the height of the block members **404**A. Distances between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E can be adjusted by exemplary variations of the height of the block members **404**B.

The block members **404**A are disposed between the semiconductor elements **12**A and the cooling block **26**A. The block members **404**A are thermally, mechanically and electrically connected to the semiconductor elements **12**A and the cooling block **26**A. The block members **404**B are disposed between the semiconductor elements **12**B and the metal blocks **14**C, **14**D and **14**E.

In the present embodiment, the power module **400** is manufactured by using the molding die **408**. The molding die **408** has inner dimensions that meet the outer shape of the power

module **400** which becomes the final product. Before the molded resin **32** is formed, a distance between the outer surfaces of the cooling blocks **26**A and **26**B sandwiching the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the block members **404** and the insulating members **30** is longer than a corresponding distance (the intended length) of the power module **400** after being molded by the molded resin **32**. In other words, the distance between the outer surfaces of the cooling blocks **26**A and **26**B before being molded by the molded resin **32** is longer than corresponding distance (the intended length) of the power module **400** when the power module **400** is completed as the final product. When the power module **400** is completed, the distance is equal to an inner dimension of the molding die **408**.

Before being molded by the molded resin **32**, natural lengths of the block members **404**A and **404**B in a stack direction are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B longer than corresponding distance of the power module **400** after being molded by the molded resin **32**. Accordingly, the heights (i.e. the lengths in the stack direction) of the block members **404**A and **404**B are relatively high. Hereinafter, a structural body in which the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the block members **404**A and **404**B and the insulating members **30** are sandwiched between the cooling blocks **26**A and **26**B before being molded by the molded resin **32** is referred to as a structural body **410**.

The molding die **408** is separated into upper molding die **408**A and lower molding die **408**B. The upper molding die **408**A and the lower molding die **408**B are put together along a parting line L. The upper molding die **408**A contacts the outer surface of the cooling block **26**A and supports the cooling block **26**A. The lower molding die **408**B contacts the outer surface of the cooling block **26**B and supports the cooling block **26**B.

In the manufacturing process of the power module **400**, before the molded resin **32** is molded, the three semiconductor elements **12**A are soldered on the metal blocks **14**C to **14**E by the solders **18**, respectively, and the other three semiconductor elements **12**B are soldered on the metal block **14**B by the solders **18**. The three block members **404**A are soldered on the metal block **14**A by the solders **24**, respectively, and the other three block members **404**B are soldered on the metal blocks **14**C to **14**E by the solders **24**, respectively. Then the semiconductor elements **12**A and **12**B and the block members **404**A and **404**B are connected by the solders **22**. Next, the insulating members **30** are temporarily fixed between the metal blocks **14**A and **14**B and the cooling blocks **26**A and **26**B, respectively. Thus, a structural body **410** in which the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the block members **404**A and **404**B and the insulating members **30** are sandwiched between the cooling blocks **26**A and **26**B is completed. Then the structural body **410** in which the semiconductor elements **12**A and **12**B, the solders **18**, **22** and **24**, the metal blocks **14**A to **14**E, the block members **404**A and **404**B and the insulating members **30** are sandwiched between the cooling blocks **26**A and **26**B is inserted into the molding die **408** and held by the molding die **408**.

When the structural body **410** is inserted into the molding die **408**, an upper end portion and a lower end portion of the structural body **410** contact with the inner surfaces of the upper molding die **408**A and the lower molding die **408**B, respectively, and are pressed in the stack direction by the molding die **408**. As described above, the distances between the semiconductor elements **12**A and the metal block **14**A can be adjusted by the exemplary variations of the height of the block members **404**A. Similarly, the distances between the semiconductor elements **12**B and the metal blocks **14**C, **14**D and **14**E can be adjusted by the exemplary variations of the height of the block members **404**B. When the upper molding die **408**A and the lower molding die **408**B are put together along the parting line L, and the structural body **410** is pressed in the stack direction, the slidable block members **406**A, **406**B and **406**C relatively slide with each other. Accordingly, the heights of the block members **404** become lower.

As the heights of the block members **404** become lower as described above, the distance between the outer surfaces of the cooling blocks **26**A and **26**B of the structural body **410** corresponds to the inner dimension of the molding die **408**, i.e. the distance between the outer surfaces of the cooling blocks **26**A and **26**B of the structural body **410** becomes equal to the inner dimension (the intended length) of the molding die **408** which is conclusively required between the outer surfaces of the cooling blocks **26**A and **26**B of the power module **400**.

In a condition where the structural body **410** is held by the molding die **408** as described above, molding resin is injected into the molding die **408** at a designated molding pressure. By injecting the molding resin into the molding die **408**, the molding resin is supplied between the cooling blocks **26**A and **26**B that are pressed by the upper molding die **408**A and the lower molding die **408**B. The molding resin becomes the molded resin **32** formed between the cooling blocks **26**A and **26**B. Accordingly, the power module **400** is completed. Then the power module **400** is picked up from the molding die **408**.

Accordingly, it becomes possible to manufacture the power module **400** which has the intended length by supplying the molding resin into the molding die **34** in a state where the block members **404**A and **404**B included in the structural body **410** between the cooling blocks **26**A and **26**B are pressed by the molding die **408**. The block pieces **406**A to **406**C relatively slide with each other, and the block members **404**A and **404**B are contracted in a state where the structural body **40** is inserted into the molding die **408** in the stack direction. The block members **404**A and **404**B are included in the frame members **402**.

According to the present embodiment, it is possible to absorb the dimensional tolerance of the power module **400** by utilizing the block members **404**A and **404**B included in frame members **402** of the power module **400**. Thus, it becomes possible to realize the dimensional management of the power module **400** in which the molded resin **32** is supplied between the cooling blocks **26**A and **26**B sandwiching the semiconductor elements **12**A and **12**B. Therefore, it becomes possible to suppress leakage of the molding resin from the molding die **408** and breakage of the semiconductor elements **12**A and **12**B or the like by the molding pressure during the molding process. Further, it is not necessary to inject extra molding resin into the molding die **32** during the molding process and to remove an excess portion of the molded resin **32** after adjusting the intended length.

According to the second embodiment, the frame members **402** include block members **404**A and **404**B having the block pieces **406**A to **406**C in order to adjust the distance between the outer surfaces of the cooling blocks **26**A and **26**B to the intended length which is conclusively required between the outer surfaces of the cooling blocks **26**A and **26**B of the power module **400**. As described above, the heat capacities of the block members **404**A and **404**B are greater than that of the spring members **20**A and **20**B of the first embodiment. Therefore, it becomes possible to improve the heat transfer perfor-

mance between the semiconductor elements 12A and 12B and the cooling blocks 26A and 26B.

In the second embodiment as described above, the block member 404 is one example of a block member, and each of the block pieces 406A, 406B and 406C is one example of a block piece.

Before the power module 400 is completed, the natural lengths of block members 404A and 404B in the stack direction are set to lengths that make the distance between the outer surfaces of the cooling members 26A and 26B longer than corresponding distance of the power module 400 when the power module 400 is completed as the final product. The distance between the outer surfaces of the cooling blocks 26A and 26B is contracted to the designated distance (the intended length) by being pressed by the molding die 408. In this case, the block members 404A and 404B are contracted in the stack direction. The second embodiment is not limited to the configuration as described above. On the contrary, before the power module 400 is completed, the natural lengths of block members 404A and 404B in the stack direction may be set to lengths that make the distance between the outer surfaces of the cooling members 26A and 26B shorter than corresponding distance of the power module 400 when the power module 400 is completed as the final product. The distance between the outer surfaces of the cooling blocks 26A and 26B is expanded to the designated distance (the intended length) by being pulled by the molding die 408. In this case, the block members 404A and 404B are expanded in the stack direction.

In the second embodiment, the block pieces 406A to 406C can relatively slide with each other in the width direction. Herein, the block pieces 406A and 406C may be connected to the metal blocks 14A to 14E. In this case, the block piece 406B can slide with regard to the block pieces 406A and 406C and the metal blocks 14A to 14E. On the contrary, the block piece 406B may be fixed to the metal blocks 14A to 14E, and the block pieces 406A and 406C may be slidably connected to the block piece 406B and the metal blocks 14A to 14E.

According to the first and second embodiments as described above, the spring members 20A and 20B are included in the frame members 16, and the block members 404A and 404B are included in the frame members 402. Further, the spring members 20A and 20B and the block members 404A and 404B are disposed in isolation from the metal blocks 14A. The present embodiments are not limited to the configurations as described above. The spring members 20A and 20B and the block members 404A and 404B are formed with the metal blocks 14A to 14E in a unified manner. In this case, the metal blocks 14A to 14E may have configurations in that the metal blocks 14A to 14E can expand or contract in the stack direction.

In the first and second embodiments as described above, the power modules 10 and 400 have multistage structures in which the semiconductor elements 12A and 12B are connected in series between the metal blocks 14A and 14B, i.e. between the cooling blocks 26A and 26B. The multistage structures include frame members 16 and 402 having the spring members 20A and 20B and the block members 404A and 404B, respectively. In the multistage structure, the three spring members 20A are provided for the three semiconductor elements 12A, respectively, and the three spring members 20B are provided for the three semiconductor elements 12B, respectively. Further, in the multistage structure, the spring members 20A and 20B or the block members 404A and 404B are connected in series between the metal blocks 14A and 14B.

However, the present embodiments are not limited to the configurations as described above. In the multistage structure, at least one spring member 20 or one block member 404 may be disposed between the cooling blocks 26A and 26B in the stack direction, i.e. between the metal blocks 14A and 14B in the stack direction. Accordingly, in a case where the semiconductor elements 12A and 12B are connected in series between the metal blocks 14A and 14B, it is not always necessary to provide two or more spring members 20 connected in series between the metal blocks 14A and 14B, or to provide two or more block members 404 connected in series between the metal blocks 14A and 14B. In this case, one spring member or one block member 404 may be provided between the metal blocks 14A and 14B. Here, one spring member 20 or one block member 404 may be connected in series with each pair of the two semiconductor elements 12A and 12B between the metal blocks 14A and 14B.

For example, in a power module 500 as illustrated in FIG. 9, the three pairs of the two semiconductor elements 12A and 12B are connected in series between the metal blocks 14A and 14B. The power module 500 further includes frame members 502 disposed between the semiconductor elements 12A and the metal blocks 14A, and frame members 503 disposed between the semiconductor elements 12B and the metal blocks 14C, 14D and 14E. The frame members 502 include block members 506, and the frame members 503 include spring members 504. The spring members 504 are similar to the spring members 20A and 20B as described above. One of the spring members 504 and one of the block members 506 are connected to each pair of the semiconductor elements 12A and 12B disposed between the metal blocks 14A and 14B.

The semiconductor elements 12B that are connected to the upper surface of the metal block 14B via the solders 18 are connected to the metal blocks 14C, 14D and 14E via the spring members 504. The semiconductor elements 12A that are connected to the upper surface of the metal blocks 14C, 14D and 14E via the solders 18 are connected to the metal block 14A via the block members 506.

The spring members 504 have similar configuration to that of the spring members 20 as described above. The block members 404 as described above may be provided instead of the spring members 504. The block members 506 are made of metallic materials having high heat transfer performance such as copper. The block members 506 are formed in block shapes. Each of the block members 506 has a single-layered block configuration and is not divided. The block members 506 are different from the divided block members 404 as described above in that the block members 506 are not divided. The one block member 506 is provided for each of the semiconductor elements 12A. The block members 506 have smaller surface areas than that of the metal blocks 14A to 14E.

Lower ends of the spring members 504 are connected to the semiconductor elements 12B via the solders 22. Upper ends of the spring members 504 are connected to the metal blocks 14C, 14D and 14E via the solders 24. Distances between the semiconductor elements 12B and the metal blocks 14C, 14D and 14E can be adjusted by expansion or the contraction of the spring members 504. Lower ends of the block members 506 are connected to the semiconductor elements 12A via the solders 22. Upper ends of the block members 506 are connected to the metal block 14A via the solders 24. Before being molded by the molded resin 32, natural lengths of the spring members 504 in a stack direction are set to lengths that make the distance between the outer surfaces of the cooling members 26A and 26B shorter than corresponding distance of the power module 500 after being molded by the molded resin 32.

Accordingly, it becomes possible to manufacture the power module **500** which has the intended length by supplying the molding resin into the molding die **34** in a state where the spring members **504** included in the structural body **502** between the cooling blocks **26**A and **26**B are expanded by the molding die **34**. The spring members **504** are expanded in a state where the structural body is inserted into the molding die **34**. Thus, similar advantageous effects to those of the embodiments as illustrated in FIGS. **1** to **8** can be obtained according to the exemplary variation as illustrated in FIG. **9**.

According to the exemplary variation as illustrated in FIG. **9**, the upper three frame members **502** include the block members **506** that are not divided in the stack direction. The heat capacities of the block members **506** are greater than those of the spring members **20**A and **20**B as described above. According to the configuration of the upper three frame members **502** including the block members **506** and the lower three frame members **503** including the spring members **504**, it becomes possible to obtain higher heat transfer performance than that of the configuration of the frame members **16** including the spring members **20**A and **20**B connected in series and the configuration of the frame members **402** including the block pieces **406**A to **406**C. As a result, according to the exemplary variation as illustrated in FIG. **9**, it becomes possible to improve the heat transfer performance, particularly heat transfer performance between the semiconductor elements **12**A and **12**B and the cooling blocks **26**A and **26**B, compared with the first and second embodiments.

According to the exemplary variation as illustrated in FIG. **9**, before being molded by the molded resin **32**, the natural lengths of the spring members **504** in a stack direction are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B shorter than corresponding distance of the power module **500** after being molded by the molded resin **32**. However, before being molded by the molded resin **32**, the natural lengths of the spring members **504** in a stack direction are set to lengths that make the distance between the outer surfaces of the cooling members **26**A and **26**B longer than corresponding distance of the power module **500** after being molded by the molded resin **32**.

According to the exemplary variation as illustrated in FIG. **9**, in a case where the spring-like members such as the spring members **20**A or **20**B are disposed between the metal blocks **14**A and **14**B and the semiconductor elements **12**A and/or **12**B, heat generated by the semiconductor elements **12**A and/or **12**B is conducted to the metal blocks **14**A and **14**B via the spring-like members. If the spring-like members as described above are disposed in the power module having the multistage structures in which the semiconductor elements **12**A and **12**B are connected to the metal blocks **14**A and **14**B via the solders **18**, the heat generated by the semiconductor elements **12**A and **12**B is conducted directly to the metal blocks **14**A and **14**B via the solders **18**. As a result, the enhanced heat transfer performance is obtained.

In the configuration where the one spring member **504** and the one block member **506** are connected in series between the metal blocks **14**A and **14**B as illustrated in FIG. **9**, it becomes possible to obtain the enhanced heat transfer performance, if the spring members **504** are disposed between the semiconductor elements **12**B and the metal blocks **14**C, **14**D and **14**E, and the block members **506** are disposed between the semiconductor elements **12**A and the metal blocks **14**C, **14**D and **14**E via the solders **18**.

According to the first and second embodiments, the spring members **20** or the block members **404** are disposed on one side of the semiconductor elements **12**A and **12**B. The spring members **20**A and **20**B or the block members **404** may be disposed on both sides of the semiconductor elements **12**A and **12**B.

Although the three pairs of the semiconductor elements **12**A and **12**B are disposed in parallel between the metal blocks **14**A and **14**B in the power module **10** or the like of the first and second embodiments as described above, the number of the pairs of the semiconductor elements **12**A and **12**B disposed between the metal blocks **14**A and **14**B are not limited to three. Plural pairs of the semiconductor elements **12**A and **12**B may be disposed in parallel between the metal blocks **14**A and **14**B. Otherwise, the one semiconductor element **12**A or **12**B may be disposed between the metal blocks **14**A and **14**B. More than three semiconductor elements may be disposed in series between the metal blocks **14**A and **14**B in the stack direction. Otherwise, the one semiconductor element **12** may be disposed between the metal blocks **14**A and **14**B in the stack direction, or the plural semiconductor elements **12** may be disposed in parallel to each other between the metal blocks **14**A and **14**B. In the latter case, for example, three semiconductor elements **12** are connected in parallel to each other between the metal blocks **14**A and **14**B.

For example, in a power module **600** as illustrated in FIG. **10**, the two semiconductor elements **12** are connected in parallel to each other between the metal blocks **14**A and **14**B. In the power module **600**, the semiconductor elements **12** are connected to the metal block **14**B via the solders **18**. The other sides of the semiconductor elements **12** are connected to the metal block **14**A via frame members **602** including spring members **604**. Lower ends of the spring members **604** are connected to the semiconductor elements **12** via the solders **22**. Upper ends of the spring members **604** are connected to the metal block **14**A via the solders **24**.

In a case where two semiconductor elements **12** are connected in parallel between the metal blocks **14**A and **14**B, it is preferable to dispose at least one spring member **604** on the upper side or the lower side of the one semiconductor element **12** and to dispose at least one spring member **604** on the upper side or the lower side of the other semiconductor element **12**. In a case where two or more pairs of the semiconductor elements **12** are disposed in parallel between the metal blocks **14**A and **14**B, single spring member **20** may be disposed on either side of single semiconductor element **12** of each of two pairs of the semiconductor elements **12** located on both ends among two or more pairs of the semiconductor elements **12**. In this case, the spring member **604** may not be disposed on any semiconductor elements **12** of the pair(s) of the semiconductor elements **12** except for the pairs located on both ends among two or more pairs.

According to the first and second embodiments as described above, the spring members **20** that can be elastically deformed in the stack direction or the slidable pieces **406**A to **406**C that can be elastically deformed in the stack direction and relatively slide to the width direction are used as a distance adjusting part which adjusts the distance between the outer surfaces of the cooling blocks **26**A and **26**B and is included in the frame member. The present embodiments are not limited to the configuration as described above. A plastic member which has plasticity and can be plastically deformed in the stack direction may be used as the distance adjusting part.

According to the exemplary variation as described above, the plastic member can be plastically deformed by being pulled or pressed by the molding die during the molding process. Distances between the semiconductor elements **12**A and the metal blocks **14**A, **14**B, **14**C, **14**D and **14**E can be adjusted by the plastic member. Distances between the metal

block **14**A and the metal blocks **14**C, **14**D and **14**E and/or distances between the metal block **14**B and the metal blocks **14**C, **14**D and **14**E can be adjusted by plastic deformation of the plastic member. The plastic member is deformable between the cooling members **26**A and **26**B. Accordingly, it becomes possible to manufacture the power module which has the intended length by supplying the molding resin into the molding die **34** in a state where the plastic member included in the structural body between the cooling blocks **26**A and **26**B is expanded or contracted by being pulled or pressed by the molding die **34**. The plastic member is expanded or contracted in the stack direction in a state where the structural body is inserted into the molding die **34**.

In the first and second embodiments as described above, the lower surfaces of the semiconductor elements **12**B are connected to the upper surface of the metal block **14**B via the solders **18**, and the upper surfaces of the semiconductor elements **12**B are connected to the metal blocks **14**C, **14**D and **14**E via the spring members **20**B or the block members **404**B. Further, the lower surface of the semiconductor elements **12**A are connected to the upper surfaces of the metal blocks **14**C, **14**D and **14**E via the solders **18**, and the upper surfaces of the semiconductor elements **12**A are connected to the lower surface of the metal block via the spring members **20**A or the block members **404**A. The present embodiments are not limited to the configurations as described above. Locations of the semiconductor elements **12**A and locations of the spring members **20**A may be interchanged. Similarly, locations of the semiconductor elements **12**B and locations of the spring members **20**B may be interchanged. The semiconductor elements **12**A and **12**B may be connected to the metal blocks **14**C, **14**D and **14**E, and may be connected to the metal blocks **14**A and **14**B via the spring members or the conductive members.

Although, as described above, the power modules **100** and **400** use the air as the coolant which performs the heat exchange at the cooling blocks **26**A and **26**B, the heat exchange is performed by using a flow path **700**, through which water is flowing, disposed between the cooling block **26**B of one power module **10**A and the cooling block **26**A of the other power module **10**B as illustrated in FIG. **11**.

The directions such as "upper" and "lower" as described above are illustrative only and used only for describing relative locations of the configuration elements such as the semiconductor elements **12**, **12**A, **12**B, the metal plates **14**A and **14**B, the spring members **20** and the cooling blocks **26**A and **26** or the like as illustrated in FIGS. **1** to **11**.

The descriptions of a power module, a method for manufacturing the power module and a molding die used for molding the power module of exemplary embodiments have been provided heretofore. The present invention is not limited to these embodiments, but various variations and modifications may be made without departing from the scope of the present invention.

The present application is based on Japanese Priority Application No. 2011-184080 filed on Aug. 25, 2011 with the Japanese Patent Office and Japanese Priority Application No. 2012-130772 filed on Jun. 8, 2012 with the Japanese Patent Office, the entire contents of which are hereby incorporated herein by reference.

What is claimed is:

1. A power module comprising:

a semiconductor element;

a first cooling member and a second cooling member configured to sandwich the semiconductor element therebetween;

a frame member configured to support the semiconductor element between the first cooling member and the second cooling member; and

a molded resin disposed between the first cooling member and the second cooling member,

wherein the frame member includes an adjusting member which adjusts a distance between the first cooling member and the second cooling member,

wherein the adjusting member includes plural block pieces that are stacked between the first cooling member and the second cooling member in a stack direction of the semiconductor element, the first cooling member and the second cooling member, and wherein the block pieces are relatively slidable with each other in a direction orthogonal to the stack direction.

2. The power module as claimed in claim **1**, wherein the plural block pieces relatively slide with each other in the direction orthogonal to the stack direction in a state where the plural block pieces are pressed by a molding die during a molding process.

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